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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1958 SUMMER MEETING IN THE EAST

AT

ITHACA, NEW YORK

June 19, 20, and 21

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Table of Contents

1958 Summer Meeting at Ithaca:

Preamble 250

Epitome 253

Programme 254

Index 274

Forms to be mailed for reservations 275

Second announcement of 1958 August meeting. 277

Preliminary announcement of 1958 Thanksgiving meeting 277

Calendar of meetings and deadlines, Season 1958–59 278

Required reading (rules and instructions for the preparation of abstracts) 278

Condensation of the Auditor's Report 279

News of the 1958 Membership List 281

Announcement of a new journal of the American Physical Society 281

Minutes of the 1958 March meeting 282

Minutes of the 1957 November meeting of the Division of Fluid Dynamics 283

Minutes of the 1958 March meeting of the New England Section 293

Minutes of the 1958 April meeting of the Southeastern Section 294

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1958 Summer Meeting in the East, Ithaca, June 19–21, 1958

THE American Physical Society will hold its **1958 Summer Meeting in the East** at Ithaca, New York, in the buildings of Cornell University, on Thursday, Friday, and Saturday, **June 19, 20, and 21.** Our Division of Electron Physics makes this its principal meeting of the year, and most of the invited papers are provided by it. Among the one hundred and three contributed papers there is a greater variety of topics than the foregoing sentence would suggest, and indeed they make this almost as diversified a meeting as our big annual events at Washington and New York. Invited papers in the field of nuclear physics have been bespoken from Cornell University and other places, and we shall also have the rare pleasure of hearing P. Debye in an evening address. The Chairman of the Local Committee is R. L. Sproull; the other committee members are H. A. Bethe, D. R. Corson, R. M. Cotts, A. L. Johnson, and R. H. Silsbee; our anticipatory thanks to all!

Ithaca is on the Lehigh Valley Railroad between New York and Buffalo. Those who travel by New York Central Railway should get off at Syracuse and take a bus for the one-hour-forty-five-minute journey to Ithaca. There is also an airport (Mohawk Airlines) and the "airline limousine will on request take members directly to dormitories or meeting halls at no extra charge. City bus transportation connects the railroad station and the campus." Automobiles are not needed for getting to the sessions, but evidently the lack of a car would be somewhat of a hindrance to excursions. "There is abundant parking space at the dormitories."

Accommodations: The Local Committee has graciously taken full charge of these, and our members have only to fill out the form printed on page 275 of this Bulletin and send it to A. L. Johnson, Department of Physics, Rockefeller Hall, Ithaca, New York.

Registration will be in the main lobby of Phillips Hall, west portal. Payment of a **registration fee** of one dollar will be required. Blackboards near the registration desks will carry notices of post-deadline papers (if any), notice of messages, and whatever the Local Committee desires to bring to the attention of our members.

All of the scientific sessions, apart from the event of Friday evening, will be held in one or another of three buildings on the Engineering Campus, of which Phillips Hall is one; the others are Olin and Kimball.

Our **Division of Electron Physics** has invited ten speakers, who are W. H. Bostick, R. C. Bradley, T. J. Bridges, W. E. Danielson, G. H. Dieke, T. M. Donohue, J. B. Hasted, Herbert Friedman, Edward Gerjuoy, and S. H. Neddermeyer. Their papers are distributed among four sessions.

Invited papers in other fields of physics number eight, mostly from Cornell University: four of these make up a Symposium on measurements of meson production; the others are by J. P. Elliott, L. G. Parratt, R. L. Sproull, and D. H. Tomboulian.

On Friday evening at half-past eight, there will be a **lecture in the new Statler Auditorium** by **P. Debye,** with the attractive title "Tales of Science and Scientists."

One hundred and three contributed papers—perhaps a record for a June meeting?—are distributed among eleven sessions.

The **timing of the sessions** will appear strange to those who are accustomed to the meetings we hold in other cities. Elsewhere we begin the morning sessions at 9:30 and the afternoon sessions at 1:30 on Saturdays, and Saturdays only; but we are informed that these hours are generally consistent with the folkways of Ithaca, and accordingly they are adopted for all three days of the meeting. There is one exception. On Friday morning Session K will begin at 9:00 and the other sessions at 9:45

so that all will be free to hear G. H. Dieke's talk which is of general interest.

The **Council of the American Physical Society** will probably not meet at Ithaca; if a meeting is convoked, the Councillors will be notified by special message.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received at the office of Professor R. L. Sproull, Cornell University, Ithaca, New York, not later than Friday, June 13. The titles of such papers as may be accepted will be written on a blackboard near the registration desk, and opportunity for the presentation of the papers will be given at the end of Session P or possibly elsewhere in the programme.

Now we turn to recreation.

A **chicken barbecue** will be held at Taughannock Falls, on the west side of Lake Cayuga ten miles from Ithaca, on *Thursday* evening beginning at 6:30. The price will be $1.50 and *advance reservations must be made:* fill out the form on page 276 and mail it as there directed. The local Committee will transfer this event to *Friday* evening if Thursday's weather appears unpropitious; announcement will be made at each of the Thursday-afternoon sessions, and those who absent themselves from these should keep an eye on the blackboards near the registration desk. If held on Friday evening, the barbecue will be terminated early enough so that everyone can get back to Ithaca to hear Professor Debye. By choice of the Local Committee, the barbecue supplants the traditional banquet.

The Ladies' Programme has been arranged by Mrs. Rhea Parratt. There will be a tea for the ladies on Thursday afternoon at the Cornell Ornithology Laboratory. This building is located in the bird sanctuary in Sapsucker Woods three miles northeast of the campus. Weather permitting, there will be a guided bird walk after the tea for any who wish to join. Transportation will be provided, leaving the north side of Carpenter Hall (engineering library building on Campus Road) at 2:00 P.M. and returning at 5:00 P.M. On Friday, an all-day trip has been planned to the Corning Glass Center and to the Hammondsport wineries. Buses will leave the north side of Carpenter Hall at 9:00 A.M. The group will visit the Corning Glass Center, including the Museum of Glass and the creation of Steuben crystal, in the morning. They will have lunch in Corning and travel to the wineries (Taylor's and Great Western). The return to Ithaca will be about 5:30 or 6:00 P.M. The cost of the tour, which includes the bus transportation but does not include lunch, will be about $2.25. For tea and for bus tour, advance reservations are requested, and a form is provided on page 276; it appears, however, that reservations for the bus tour may be made on Thursday at the registration desk up to four o'clock.

The first Ithaca meeting of the American Physical Society. There has been only one meeting of our Society at Ithaca, so far, but that was a historic one. Held in June of 1930, it was the first of the chain of "Summer Meetings in the East" which has not since been broken excepting during wartime and once for the sake of the 1950 Mexico Meeting. Though I was not then an officer of the Society, I distinctly remember being told that the Summer Meetings were intended to be playful, with plenty of opportunities for recreation surrounding a rather small scientific programme. Playful the first of them certainly was, and the orally preserved traditions of the Society included the tale of the all-day tennis tournament, at the end of which the then Treasurer of the Society—G. B. Pegram, now Treasurer Emeritus—triumphed by winning, 2 sets to 1, over a soon-to-be-distinguished physicist twenty years younger than himself. I have looked up the records of this meeting (which I missed) to see how this amplitude of free time was achieved. It was found that there were only two consecutive sessions of 33 contributed papers, all of which were squeezed into two consecutive sessions on the first day (Thursday) of the three, and only five invited papers, one by Sir William Bragg. Also scheduled were, on Friday afternoon, "informal conferences" in various fields of physics. We cannot match in 1958 this amplitude of leisure though the sessions will be fewer and shorter than is usual. The 1930 record does not include the number of registrants but does comprise the information that there was an excursion to the Corning Glass Works and a picnic at which 247 were present (Local Committee is asked to compare the 1958 figure with this). Also an (unspecified) prize was given to the man who had driven the greatest distance to get to Ithaca: he was A. S. Adams, who started from Golden, Colorado.

We return to the present time.

Prospective meetings and deadlines of the Society will be found on page 278 of this Bulletin, and preliminary announcements of the Vancouver meeting in August and of the Chicago meeting in November on page 277.

Make a habit of reading the instructions for the preparation of abstracts, which in this Bulletin appear on page 278. From time to time they become more stringent, for their purpose is to reduce the waste of labor and loss of time spent in editing

(i.e., in preparing for the press) abstracts that are badly prepared, and the importance of diminishing this waste is steadily increasing. We are sincerely grateful to the members, rising in number, who at the beginnings of their abstracts put the title, the author's name, and the author's institution in the proper order.—Telegraphed abstracts are not put into print, and telegrams announcing that abstracts are on their way are quite without influence.

Errata pertaining to abstracts in this issue will be published in a later issue of this Bulletin if received not later than Monday, June 30, by Miss Ruth Bryans, American Institute of Physics, 335 East 45th Street, New York 17, New York. Write out the corrections in the form "Instead of . . . read. . . ." The privilege of having an erratum published is not accorded for the purpose of enabling people to publish new data or to restore material cut out because the abstract was too long.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE 1958 ITHACA MEETING

(Personal names are those of invited speakers, except at the ends of lines where they are those of halls. DEP stands for Division of Electron Physics).

Thursday Morning

9:30 A. Metals and semiconductors. Kimball B-11.

9:30 B. DEP: Hasted, Bradley, Gerjuoy. Olin M.

9:30 C. Theoretical Physics. Phillips 101.

Thursday Afternoon

1:30 E. Gaseous electronics. Phillips 101.

1:30 F. Germanium and silicon. Olin M.

1:30 G. Sproull, Parratt, Tomboulian. Kimball B-11.

Thursday Evening

6:30 Chicken Barbecue at Taughannock Falls State Park.

Friday Morning

9:45 J. Magnetic resonance; x-rays; molecular spectra. Phillips 101.

9:00 K. DEP: Dieke, Friedman, Donohue. Olin M.

9:45 L. Meson production: DeWire, Woodward, Cocconi, Silverman. Olin R.

9:45 M. Electron emission, I. Kimball B-11.

Friday Afternoon

1:30 N. Electron emission, II; DEP: Danielson, Bridges. Olin M.

1:30 P. Magnetism; chemical physics; post-deadline papers, if any. Phillips 101.

1:30 Q. Nuclear physics, I. Kimball B-11.

Friday Evening

8:30 S. P. Debye. Statler Auditorium.

Saturday Morning

9:30 T. Elliott; nuclear physics, II. Kimball B-11.

9:30 U. DEP: Bostick, Neddermeyer. Olin M.

9:30 V. Solid-state physics, mostly crystals. Phillips 101.

PROGRAMME

THURSDAY MORNING AT 9:30

Kimball B-11

(R. L. SPROULL presiding)

Metals and Semiconductors

A1. Stress-Assisted Precipitation on Dislocations. FRANK S. HAM, *General Electric Research Laboratory.*—We have re-examined the theory of Cottrell and Bilby[1] concerning the rate of precipitation of solute atoms on edge dislocations. These authors had to neglect diffusion in comparison with stress-induced drift in deriving a result valid in the early stages of precipitation. In contrast, our result includes both diffusion and drift but is most accurate in the later stages and represents a reasonable interpolation to the Cottrell-Bilby result at earlier times. If the interaction energy of a solute atom and a dislocation is given by $U=-(A\sin\theta)/r$, we show that the precipitated fraction W may be approximated by that derived from a simple diffusion problem with each dislocation replaced by a cylinder with capture radius $R=(0.445)A/kT$. The dislocation density deduced with our theory from experimental data is roughly a factor of two less than that obtained from a formula suggested by Harper,[2] $(1-W)=\exp[-(t/\tau)^{\frac{1}{2}}]$. If we plot $\ln[1/(1-W)]$ *vs* $t^{\frac{1}{2}}$, our result departs somewhat from a straight line. Therefore the very excellent agreement between Harper's formula and the results of certain experiments seems to some extent fortuitous.

[1] A. H. Cottrell and B. Bilby, Proc. Phys. Soc. (London) **A62**, 49 (1949).
[2] S. Harper, Phys. Rev. **83**, 709 (1951).

A2. Deduction of the Volume-Dependence of the Cohesive Energy from Shock Wave Compression Measurements on Solids. G. B. BENEDEK, *Harvard University.*—Measurements of the relation between the shock front velocity (U_s) and shock particle velocity (U_p) in 27 metals recently have been published.[1] By using the Mie-Gruneisen equation of state and the Rankine-Hugoniot relations it is possible to deduce directly from the experimentally determined relation between U_s and U_p the volume dependence of the cohesive energy $\Phi(v)$ and its second derivative $\partial^2\Phi/\partial V^2$. Calculations of $\Phi(v)$ and $\partial^2\Phi/\partial V^2$ have been carried out for the metals Be, Cu, Ag, Al, Co, and Ni over a volume compression range which is typically as large as 25%. The theory underlying this deduction and the numerical results for the metals mentioned in the foregoing will be presented.

[1] Walsh, Rice, McQueen, and Yarger, Phys. Rev. **108**, 196 (1957).

A3. Hall Constants and Thermoelectric Power of Titanium Alloys. H. T. PINNICK, *Electro Metallurgical Company.*—The change in electrical resistivity of titanium when alloyed with silver, aluminum, and tin has been shown to be essentially independent of the valence of the solute.[1] In an effort to study changes of electron concentration in these same alloy systems, their Hall constants and thermoelectric power have been measured. Qualitatively, the Hall constants and thermoelectric powers of the three alloy systems are quite similar. However, in contrast to the case of electrical resistivity, there is a definite dependence on solute valence. The initial slope of Hall constant as a function of concentration for the silver alloys is greater by a factor of two than for the tin alloys, while the initial slopes of thermoelectric power at 80°K as a function of concentration for these two alloy systems have different signs.

[1] Ames and McQuillan, Acta Met. **4**, 619 (1956).

A4. Resistance Measurements in Thin Bismuth Films.* J. M. GALLIGAN† AND C. E. DRUMHELLER, *University of Illinois.*—Evaporated thin films of bismuth deposited on cellulose nitrate substrate have been studied. Measurement of the temperature dependence of resistance in films in the resistance range from 12–360 ohms showed that the resistance decreased with an increase in temperature. The maximum activation energy was about 0.027 electron volt in this resistance range. In the resistance range above 400 ohms the resistance increased with increasing temperature, with activation energies as low as 0.009 ev. The reason for this negative activation energy is not understood, but the measurements are reproducible and it is well outside experimental error. No simple model could be proposed to explain this negative activation energy in the absence of information about the density and type of electrical carriers. Aging the films in air, for one month, had the effect of increasing the activation energies.

* This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.
† Now at Edgar C. Bain Laboratory for Fundamental Research, U. S. Steel Corporation.

A5. (Abstract withdrawn.)

A6. Ionized Impurity Scattering and Hot Electrons. I. ADAWI, *RCA Laboratories.*—The distribution function of electrons in a nonpolar semiconductor in the presence of an electrostatic field E and ionized impurity scattering (in addition to acoustical phonon scattering) has been obtained by a method previously[1] discussed. Deviations from Ohm's

law at low fields are studied, and it is found that the change in the mobility $(\mu-\mu_0) \propto E^2$. The proportionality constant is highly sensitive to ionized impurity scattering and changes appreciably from its value for pure lattice scattering for μ_{LO}/μ_{IO} as low as 10^{-4}. (μ_{LO} and μ_{IO} are the low field lattice and impurity mobilities, respectively.) Theory is compared with experiment, and the parameter μ_{LO}/c (c = speed of sound) enters in this comparison. The discrepancy of μ_{LO}/c from its actual value measures approximately the ratio of the total energy losses by electrons in the crystal to losses to the acoustical phonons alone. Therefore, the dependence of the discrepancy on temperature could afford a clue to the nature of energy losses. However, the situation still calls for further experiments, particularly on samples with a highly ionized impurity content and at different temperatures.

[1] I. Adawi, Bull. Am. Phys. Soc. Ser. II, 3, 13 (1958).

A7. Infrared Properties of Alpha and Beta Silicon Carbide. W. G. SPITZER, *Bell Telephone Laboratories.*—Infrared transmission and reflection measurements from 1.0 to 25μ have been made on several samples of green alpha (hexagonal) SiC having different surface preparations. The spectral shape of the residual ray band is strongly dependent upon the surface condition and shifts about 0.1μ between the ordinary and extraordinary rays. For the ordinary ray two reflection bands have been resolved, indicating the presence of two strong absorption bands. At present the data are insufficient to assign these bands to particular branches of the vibration spectrum. Transmission measurements at 297°K using alpha SiC samples of different thicknesses and impurity concentrations permitted the identification of intrinsic lattice absorption bands at ~1697, 1618, 1550, 1391, and 1315 wave numbers (cm^{-1}). The first three seem to be combination bands of those observed in the reflectivity measurements. The last two may be combination bands between the optical and acoustical branches of the vibration spectrum. Measurements of the infrared transmission of polycrystalline beta (cubic) SiC (t = 1000 to 15 000 A) show a single absorption band at 12.60±0.10μ (794 cm^{-1}). This should be accompanied by a reflectivity band at ~12.0μ which is close to one of the reflection peaks observed on the alpha SiC.

A8. Field Effect in PbS Films in Various Gas Ambients. J. O. VARELA AND JAY N. ZEMEL, *U. S. Naval Ordnance Laboratory.*—Field effect measurements on several PbS films were made using the method of H. E. Sorrows.[1] The field effect was observed on these films in gas ambients of dry and wet N_2 and O_2, and measurements were made as a function of temperature. In all four ambients the time constant, τ, and the cell resistance, R_0, decreased with an increasing temperature while the trapped surface charge, α, remained almost constant. When the wet O_2 ambient was introduced, the values of α and R_0 were found to decrease whereas τ increased at a given temperature. Any set of the foregoing parameters may be duplicated by reproducing the same temperature and gas ambient. The value of τ obtained by the field effect method agrees with that obtained from photoconductive measurements. Knowing the values of α and τ, it is possible to calculate the time into and out of the surface traps. The dependence of these latter quantities on ambient and temperature was similar to that of τ.

[1] H. E. Sorrows, Bull. Am. Phys. Soc. Ser. II, 2, 131 (1957).

A9. Optical Properties of Indium Arsenide. J. R. DIXON AND D. P. ENRIGHT, *U. S. Naval Ordnance Laboratory.*—Infrared absorption of single crystal n- and p-type indium arsenide has been studied in the wavelength range from 1 to 15 microns. It was found that, for the n-type material, the absorption constant, k, for wavelengths on the long wavelength side of the intrinsic absorption edge (~4 microns) decreases with an approximate λ^3 dependence. The magnitude of the absorption constant is proportional to carrier concentrations ranging from 10^{16} to 10^{18} cm^{-3}. Maximum transmissions of over 50%, approaching the theoretical limit, were obtained for samples 1 mm thick and having carrier densities ranging downward from 10^{17} cm^{-3}. For p-type material at room temperature, the absorption on the long wave side of the absorption edge which has been attributed to transitions between light and heavy hole valence bands[1] has been studied as a function of carrier concentration. It was found that the maximum absorption resulting from such transitions is proportional to the concentration of holes in the valence band as expected. In addition, absorption in the region of the intrinsic absorption edge has been determined as a function of carrier concentration.

[1] F. Stern and R. M. Talley, Phys. Rev. 108, 158 (1957).

A10. Surface Transport Theory. JAY N. ZEMEL, *U. S. Naval Ordnance Laboratory.*—A detailed study of Schrieffer's[1] derivation of the reduction in mobility of excess surface carriers indicates that the contributions of bulk and surface carriers are not fully treated. Using his notation

$$K(v_{zs}) = \int_0^{v_{zs}} \frac{m dv_z}{q\tau E_z(v_z,\epsilon)},$$

where E_z is the space charge field and ϵ is $(mv_z^2/2) - q(\psi - \psi_s)$. So long as $\psi < \psi_b$, the bulk potential v_z will go to zero. However, if $\psi > \psi_b$, v_z will never be zero, and the definition of $k(v_{zs})$ is no longer correct. Considerations based on this lead to a total current/square which separates quite naturally into a bulk and surface term. An effective mobility is then deduced from the surface contribution. A new potential model is introduced which varies linearly with distance up to a point z_0 and then is independent of the distance. Comparisons with previous models will be presented.

[1] J. R. Schrieffer, Phys. Rev. 97, 641 (1955).

A11. Hall Coefficient and Mobility of Electrons in GaAs. P. V. GRAY AND H. EHRENREICH, *General Electric Research Laboratory.*—A possible explanation of the observed maximum[1] in the Hall coefficient R_H of n-type GaAs, occurring just before the onset of intrinsic conduction, is given using the conduction band structure proposed by Callaway.[2] The band minimum is supposed at $k=0$, with an associated experimentally determined mass of 0.04[3]. Another minimum along the [111] direction, assumed here precisely the same as in Ge, is somewhat higher in energy (by perhaps 0.2–0.4 ev). The effect is attributed to two-band conduction which causes R_H to increase with temperature above 500°K until intrinsic excitation occurs and R_H decreases rapidly. The occurrence of the maximum is not critically dependent on exact values of the mass, energy separation, and location in k space of the secondary minimum. The *shape* of the maximum, which is not well determined experimentally, is sensitive to this choice. Polar scattering appears to be the dominant mechanism determining the mobility. The temperature dependence of the *Hall* mobility, neglecting intervalley scattering, agrees well with experiment.[1] The calculated magnitude, using optical data,[3] is within the present experimental uncertainty.

[1] Edmond, Brown, and Cunnell, Rugby Semiconductor Conference, Phys. Soc. (London) (1956).
[2] J. Callaway, J. Electronics 2, 330 (1957); Barcus, Perlmutter, and Callaway, Bull. Am. Phys. Soc. Ser. II. 3, 30 (1958).
[3] Picus, Burstein, and Henvis, Bull. Am. Phys. Soc. Ser. II, 2, 66 (1957).

THURSDAY MORNING AT 9:30

Olin M

(H. D. HAGSTRUM presiding)

Invited Papers of the Division of Electron Physics

B1. Ionizing Collisions in Gases and at Surfaces. J. B. HASTED, *University College, London.* (30 min.)

B2. Secondary Ion Emission from Metal Surfaces. R. C. BRADLEY, *Cornell University.* (30 min.)

B3. Inelastic Atomic Collision Processes. EDWARD GERJUOY, *Westinghouse Research Laboratories and University of Pittsburgh.* (30 min.)

THURSDAY MORNING AT 9:30

Phillips 101

(G. E. UHLENBECK presiding)

Theoretical Physics

C1. (Abstract withdrawn.)

C2. A New Form of the Four-Component Fermion Theory. A. O. BARUT, *Syracuse University.*—The two-component fermion theory of Feynman and Gell-Mann has been linearized in the time coordinate. This leads to a four-component theory with an indefinite metric in spin space, states with negative norm corresponding to the charge-conjugate particles. The Hamiltonian is now quadratic in the momenta which allows a straightforward transition to the nonrelativistic Pauli equation. The equation describes simultaneously the two charge conjugate states whose separation is made explicitely, as for the spin 0 case. As a matter of fact, spin 0 and spin $\frac{1}{2}$ cases can be treated step by step in complete analogy. Physical interpretation of the theory, a Foldy-Wouthuysen type free-particle representation, and the interaction forms have been discussed.

C3. Group Properties of the Electron-Neutrino.* FEZA GÜRSEY, *University of California, Berkeley, and Brookhaven National Laboratory.*—The isotopic spin concept is valid only if electromagnetic forces are neglected. If we assume an electromagnetic origin for the rest mass of the electron in the zero-mass limit, the neutrino-electron system should emerge as an isotopic doublet. Grouping the left-handed neutrino and the charge conjugate of the left-handed electron into a 4-spinor field λ, and similarly representing the right-handed fields by λ', we note that in this limit both λ and λ' satisfy a Dirac equation for zero mass and admit unitary Pauli groups with different parameters. This 8-parameter group also splits into a 4-dimensional Euclidean rotation group and two phase groups. Now in the case of a two component (left-handed) neutrino, the system is described by λ and the 2-component right-handed electron e_R. The high symmetry is then reduced to the Pauli group for λ that gives isorotations and to two phase groups that are, respectively, isomorphic with hypercharge and lepton-number gauge transformations. Such an isomorphism between the lepton group and the group of strong interactions could arise only naturally in a composite particle scheme which should also involve at least one baryon field.

* Work done under the auspices of U. S. Atomic Energy Commission and the International Cooperation Administration.

C4. Connection between Parity and Strangeness. J. J. SAKURAI, *Cornell University.*—The conjecture that the weak interactions are "minimal" in the sense that nature picks out just one (χ_+) of the two eigenspinors (χ_+ and χ_-) of γ_5 has been confirmed by various recent experiments. The important question still remains why both eigenspinors must appear symmetrically in the parity-conserving strong interactions. In the case of the charge-symmetric pion-nucleon interaction inverse invariance (G invariance) in isotopic spin space necessitates the symmetric appearance of χ_+ and χ_-. An attempt is made to generalize this view to strange-particle interactions as first suggested by Gell-Mann. For strangeness-conserving processes, even if we start with interactions containing χ_+ only, we can generate interactions containing χ_- by means of G conjugation. (*For simplicity* we have assumed that the Yukawa interaction *must* involve derivatives of the meson field.) For strangeness-violating processes the foregoing procedure leads to inadmissible interactions that do not conserve electric charge; hence there is no compelling reason why χ_- should appear in addition to χ_+. Thus if we accept the view that the strong interactions are invariant under G conjugation, we have some understanding of the puzzling fact that strangeness-conserving processes conserve parity whereas strangeness-violating processes may not.

C5. Λ-nucleon Interaction in the Hypernucleus $_{\Lambda}Be^{9}$.* KIU S. SUH, *Cornell University*.—A variational method has been used to calculate the strength of the Λ-nucleon interaction required to account for the observed binding of $_{\Lambda}Be^{9}$. The hypernucleus is treated as a three-body system (two alpha particles and the hyperon) in which the spin average of the Λ-nucleon interaction is effective. Calculations have been made for two assumed ranges of the Λ-nucleon interaction potential: that corresponding to the K-meson Compton wavelength and that corresponding to one-half the pion Compton wavelength. This analysis of the binding of $_{\Lambda}Be^{9}$ indicates that the same Λ-nucleon interaction is effective here as is in $_{\Lambda}Be^{5}$ provided that the alpha-alpha nucleon interaction in $_{\Lambda}Be^{9}$ is such as to prevent appreciable overlapping of the two alpha particles. This analysis agrees with the conclusion by Dalitz and Downs[1] that, if the hypernuclear binding energies are ascribed to a two-body Λ-nucleon interaction, the interaction must be spin-dependent.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] R. H. Dalitz and B. W. Downs, Phys. Rev. (to be published).

C6. Semiphenomenological Theory of Σ^{+} Hyperon-Proton Scattering up to 150 Mev. R. BRYAN, J. DE SWART, AND R. MARSHAK, *University of Rochester*, AND P. S. SIGNELL, *Bucknell University*.—A semiphenomenological potential has been found which gives an excellent fit of all proton-proton scattering data up to 150 Mev.[1] If it is assumed that there is a universal pion-baryon coupling, the Σ hyperon-nucleon interaction in the isotopic spin $\frac{3}{2}$ state should be identical with the proton-proton potential (without the Pauli principle). The differential cross section and polarization for Σ^{+}-p scattering has been calculated at 40, 100, and 150 Mev in the laboratory system on the basis of the successful p-p potential. The comparison of these results with experiment should provide a test of the hypothesis of the universal pion-baryon coupling.[2]

[1] P. S. Signell and R. E. Marshak, Phys. Rev. **109**, 1229 (1958).
[2] M. Gell-Mann, Phys. Rev. **106**, 1296 (1957); D. B. Lichtenberg and M. H. Ross, Phys. Rev. **103**, 1131 (1956).

C7. π^{-}-P Scattering and the Dispersion Relation at Higher Energies.* HONG-YEE CHIU, *Cornell University*.—The real part of forward scattering amplitude Ref(0) in π^{-}-P scattering has been calculated to 800-Mev laboratory pion energy from dispersion relation theory. The curve crosses the ω axis with a negative slope at about 750-Mev, which is close to the second resonance peak of π^{-}-P scattering. It is possible to correlate d Ref(0)/$d\omega$ to the resonant states involved. At low energies it has been found that there is a discrepancy between the observed d Ref(0)/$d\omega$ and that predicted by Chew-Low's cutoff theory, the discrepancy being such that the relation between η^{3} cot$\delta_{31}/\omega_{c}^{2}$ and ω_{c}^{2} is not linear even in the region 120–190 Mev. At higher energies it is hoped that the value of d Ref(0)/$d\omega$ may help determine the resonant states and give justification to a recent model.[1]

* Supported in part by the joint program of the Office of the Naval Research and the U. S. Atomic Energy Commission.
[1] R. R. Wilson, "A new isobaric state of the proton?" (private communication).

C8. Configuration Mixing in the C^{14} Ground State. ELIZABETH BARANGER AND SYDNEY MESHKOV, *University of Pittsburgh*.*—An analysis of recent $C^{14}(d,t)C^{13}$ experiments[1] indicates configuration mixing in the C^{14} ground state. The experiments[1] lead to the $\frac{1}{2}-$ ground state, $\frac{1}{2}+3.08$-Mev and $\frac{3}{2}+3.86$-Mev levels of C^{13}. The angular distributions to these states can be fitted by Butler stripping curves with $l_n=1$, 0, and 2, respectively. Inasmuch as the reactions proceed via a pickup mechanism, the 0+ ground state of C^{14} must contain admixtures of $(1s)^4(1p)^8(1d)^2$ and $(1s)^4(1p)^8(2s)^2$ to the usual $(1s)^4(1p)^{10}$ configuration. Preliminary estimates give an amount of admixture of $(1s)^4(1p)^8(1d)^2$ large enough to produce the required cancelation of the $C^{14}\rightarrow N^{14}$ beta-decay matrix element.[2] The amount of admixture of the $(1s)^4(1p)^8(2s)^2$ configuration is small. These results suggest the possibility of describing the properties of the mass 14 polyad using only central and spin-orbit interactions without invoking any tensor force.

* Work done in the SMS Radiation Laboratory and assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] W. E. Moore and J. N. McGruer, Bull. Am. Phys. Ser. II, 3, 198 (1958).
[2] D. R. Inglis, Revs. Modern Phys. **25**, 390 (1953).

C9. Lorentz-Type Contraction of Vortex Rings in Ideal Fluids. W. R. MELLEN, *Alfred University*.—A theory of the structure of vortex rings, based on the vector wave equation, leads to a predicted contraction of the rings in the direction of motion by a factor of $(1-w^2/V^2)^{\frac{1}{2}}$ where w is the velocity of the vortex ring and V is the velocity of waves in the fluid. The theory assumes a steady-state solution of the wave equation for the particle velocity vector and thus requires the particle velocity vector to satisfy the vector Laplacian. By making first a Galilean transformation from a system at rest in the fluid to a system moving with the vortex ring and second, a transformation involving a contraction, the vector Laplacian is again obtained in the new coordinate system for steady-state conditions. The contraction is similar to the Lorentz contraction of the theory of relativity. If nuclear particles are assumed to be some kind of electromagnetic vortex ring in a world fluid, then the Lorentz contraction could be the result of the same kind of contraction that more ordinary vortex rings experience as a result of their motion. The fluid or particle velocity in the world fluid is assumed to be similar to Poynting's vector in free space.

C10. Solutions of the Boltzmann Equation for an Electron Beam in an External Guide Field.* JOACHIM B. EHRMAN, *U. S. Naval Research Laboratory*.—In investigating the stability of the electron beam in dePackh's proposal for a Budker-type accelerator,[1] the solution of the time-dependent Boltzmann equation is carried out in three consecutive approximations of increasing refinement. The first approximation replaces the actual external quadrupole magnetic guide field by an electric field dependent on r, but independent of θ and z, and neglects changes of the distribution in times which are short compared to the operating cycle of the accelerator (quasi-static approximation). The second approximation gives the θ and z dependence of the quasi-static distribution to first order in a perturbation calculation, in which the difference between the magnetic guide field and the electric pseudo-guide field is the perturbation. In these two approximations, the adiabatic invariance of action integrals takes the place of explicit time dependence. The third approximation is a first-order perturbation calculation in high-frequency components of the distribution. The investigation of stability becomes a problem in the expansion of a function in terms of a complete orthogonal set of eigenfunctions of definite frequencies.

* NRL Problem HO2-21.
[1] D. C. dePackh, "A Quasi-Equilibrium Electron Guide Field", Third Internat. Conference on Ioniz. Phenomena in Gases, Venice, Italy, 1957.

C11. On the Uncertainty and Complementarity Principles. JOSEPH G. BARREDO, *C.S.I.C.*—Einstein's, Schrödinger's, de Broglie's, Bohm's, and others' doubts[1] about the validity of von Neuman's theorem denying the existence of "hidden" (internal) coordinates, and about the validity of uncertainty and complementarity principles, are confirmed by the consideration that the particle "hidden" coordinates can be calculated by the trion binding energy.[2] The trion concept also confirms the fact that the two-component neutrino theory is not

enough to explain the experimental data. Since particles are neither points nor invariants, external coordinates have no microscopic meaning. Therefore, when parity and time invariance are abandoned, retaining the use of external coordinates, the number of constants increases to 20, indicating the need for new physical concepts. The "hidden" coordinates indicate also why relativity, quantum mechanics, and even Coulomb's and Ohm's laws do not hold for distances $<10^{-13}$ cm and why Dirac's equation or any vector, tensor, or even spinor equation that is linear is not enough to describe a particle.

[1] See, e.g., N. Yukawa, Progr. Theoret. Phys. 16, 680 (1956); W. Heisenberg, Revs. Modern Phys. 29, 269 (1957); D. Bohm, *Causality and Change in Modern Physics* (Van Nostrand and Company, Princeton, New Jersey, 1957).

[2] J. G. Barredo, Naturwissenschaften 15, 51, 346 (1956); Bull. Am. Phys. Soc. Ser. II, 2, 268 (1957); *ibid.* 3, 71 (1958).

THURSDAY AFTERNOON AT 1:30

Phillips 101

(M. A. BIONDI presiding)

Gaseous Electronics

E1. Fluorescence Efficiency of Gases Under α-Particle Bombardment. C. G. MILLER, *University of California, Santa Barbara* AND M. FORTE, *C.I.S.E., Milan, Italy.*—The light emitted by various gases under bombardment by alpha particles from polonium has been studied by means of a photomultiplier pickup, using the visible spectral region. The size distribution of the light pulses as a function of gas pressures and compositions has been analyzed with a variable bias discriminator. The output of the visible component from A is strongly enhanced by small amounts of N_2, between 1 and 4% showing maximum light output. The gases O_2 and air are remarkably low in light output and depress the emission of A when mixed with it. In the cases of O_2, N_2, A-N_2 mixtures and pure tank A, the light output for the same energy absorption in the gas is increased markedly as the pressure is decreased, indicating the importance of the self-quenching process.

E2. Ion Balance and Light Emission in the Helium Afterglow. DONALD E. KERR AND MERLE N. HIRSH, *The Johns Hopkins University.*—In the afterglow following a pulsed discharge at pressures from 3 to 20 mm Hg in helium, the time dependence of I/n, the ratio of intensity of emitted molecular bands to electron density, suggests: (1) the light results from recombination between an electron and a He_2^+ ion; (2) at late afterglow times the rate of loss of He_2^+ ions by recombination is much smaller than that by the predominant mechanism of ambipolar diffusion which occurs at a measured rate expressed by a value for $D_a p$ of 794. The light intensity is not, in general, proportional to the square of the electron density. The electron density variation at late times reveals simultaneous loss by ambipolar diffusion and creation by collisions between metastable molecules. The ion so created may be He_2^+, or it may be He^+, which is rapidly converted by three-body collisions to He_2^+. The creation of these ions is not reflected in the time dependence of the I/n ratio. We suggest that these ions may be formed in high vibrational states which do not yield molecular light directly or participate in collisional de-excitation to the ionic ground state (which we assume does yield molecular light by recombination). Various possible types of recombination mechanisms will be discussed.

E3. Nonlinear Effects of Recombination in Helium Afterglow. ERNEST P. GRAY,* *The Johns Hopkins University.*—The time dependence of the concentrations of the long-lived components of a helium afterglow have been studied theoretically, taking explicit account of the nonlinearity introduced by recombination. The reactions assumed to occur in the afterglow were discussed in the previous paper. The corresponding rate equations are solved under the following assumptions: (1) the plasma is macroscopically neutral; (2) charged-particle diffusion is ambipolar; (3) all diffusion terms, $\nabla^2 C$, can be replaced by $-C/\Lambda$, where Λ is the diffusion length of the lowest mode in the absence of the nonlinearity; (4) all "fast" reactions occur instantaneously; (5) dissociative recombination and ionizing collisions between molecular metastables are the only "slow" reactions; (6) the time dependence of the molecular metastable concentration is given by the exponential experimentally observed at late times. If the fraction of excited atoms converted to molecular ions (as compared to the fractions decaying by radiation, undergoing radiationless quenching, and converted to molecules) is negligible, closed-form solutions are obtained. Otherwise, the accidental near-equality of the molecular-ion ambipolar diffusion coefficient, and twice the molecular-metastable diffusion coefficient, is utilized to relate an approximate solution to solutions of a linear second-order differential equation.

* William S. Parsons Fellow, on leave from the Applied Physics Laboratory, Silver Spring.

E4. Differential Method for the Measurement of the Energy Required to Produce an Ion Pair in a Gas. IRA T. MYERS, *General Electric Company.**—The energy required to produce an ion pair was measured differentially in a 50-cm long gas cell, using the relation $W=\Delta E/I$, where ΔE is the energy absorbed by the gas per second and I is the ionization current. The source of radiation was a 2-Mev Van de Graaff electron accelerator. The ionization currents I were measured by standard techniques, although some difficulty was experienced in attaining saturation at the high dose rates involved. The absorbed energy ΔE was measured with a total beam calorimeter by taking beam power measurements with and without gas in the absorption chamber. In order to achieve the accuracy and stability required for difference measurements, a high-stability calorimeter and beam current integrator were built. Magnetic fields were used to reduce the effects of scattering.

* This paper is based on work performed for the U. S. Atomic Energy Commission.

E5. Electron Impact Study of CO with a Lozier Apparatus. MORTON A. FINEMAN AND AMERICO W. PETROCELLI,* *Providence College.*—A Lozier apparatus incorporating the retarding potential difference method for obtaining an essentially monoenergetic electron beam has been employed to study CO. The ionization efficiency curves obtained for positive ions when retarding potentials were applied to the ion collector showed four distinct breaks. The processes corresponding to these breaks were identified and the appearance potential for zero kinetic energy of the particles was determined. One

process interpreted as the formation of $O^+(^4S)$ and $C(^3P)$ has never before been reported. Processes leading to the formation of negative ions were also investigated. Besides a dissociative electron attachment process leading to $O^-(^2P)$, two other processes leading to negative ions were also observed. Both of these reactions were polar dissociation processes. From the data of the polar dissociation process leading to $C^-(^4S)$ and $O^+(^4S)$, it is possible to evaluate the electron affinity of C. Since the agreement of $A_0(C^-)$ and $A_0(O^+)$ was rather poor, the EA(C) was calculated using the more reliable value of $A_0(O^+)$. An electron affinity of 1.4 ± 0.3 ev was calculated which agrees within experimental error with the value determined by Lagergren.[1]

* This research was supported by the U. S. Atomic Energy Commission.
[1] C. R. Lagergren, Doctoral Dissertation, Series No. 15, 940, University Microfilms, Ann Arbor, Michigan.

E6. Photoionization Analysis by Mass Spectroscopy.* G. L. WEISSLER, G. R. COOK, M. OGAWA, AND J. A. R. SAMSON, *University of Southern California.*—A vacuum ultraviolet monochromator has been combined with a mass spectrometer similar to previously reported instrumentation[1] to study photoionization processes between 1570 A and 430 A. Monochromatic photons were used to ionize A, Ne, O_2, N_2, CO, NO, CO_2, N_2O, and NO_2, and preliminary measurements of ion intensity as a function of photon energy have been obtained for the parent ions together with their fragments. The onset of ionization and the plot of ions per unit photon flux vs λ will be compared to previously reported work on photoionization cross sections.[2] Dissociative ionization energies have also been determined for some of the foregoing gases, and the results for N_2O favor the N_2 dissociation energy of 9.8 ev.

* This work has been in part supported by the Geophysical Research Directorate of the Air Force Cambridge Research Center and the Office of Naval Research.
[1] Hurzeler, Ingram, and Morrison, J. Chem. Phys. **28**, 76 (1958).
[2] G. L. Weissler, "Photoionization in gases," *Handbuch der Physik* (Springer-Verlag, Berlin, 1956), Vol. XXI.

E7. (Abstract withdrawn.)

E8. Effect of Active Species on Ultra-High Vacuum Measurements. T. W. HICKMOTT, *General Electric Research Laboratory.*—It has been emphasized that the flash filament technique is limited in its applicability to gases which do not strongly interact with the pressure-measuring device[1] and effects of such interactions for easily dissociable gases, H_2 and O_2, have been shown.[2] Examination, by means of an omegatron mass spectrometer, of the gases in an ultra-high vacuum system containing H_2, when an inverted ionization gauge measures pressure, shows that CO is present in larger amounts than the H_2 introduced, and that H_2O_2, H_2O, and CH_4 are also significant contaminants. Interaction of atomic hydrogen, produced by the hot tungsten ionization gauge cathode, with the glass walls of the vacuum system is believed responsible. Similar phenomena have been observed in O_2-containing systems at low pressure, where CO and CO_2 are present in large amounts.[3] We have been able to reduce contaminants to negligible amounts by using as gauge cathode a lanthanum boride-coated tantalum filament which operates at ~1300°K, thus reducing production of atomic hydrogen or oxygen.

[1] G. Ehrlich, J. Phys. Chem. **60**, 1388 (1956).
[2] T. W. Hickmott and G. Ehrlich, J. Chem. Phys. **24**, 1263 (1956).
[3] H. D. Hagstrum and J. T. Tate, Phys. Rev. **59**, 509 (1941).

THURSDAY AFTERNOON AT 1:30

Olin M

(W. W. TYLER presiding)

Germanium and Silicon

F1. Hall Effect in Germanium at 20 kmc. G. E. HAMBLETON AND W. W. GÄRTNER, *U. S. Army Signal Engineering Laboratories.*—Equipment is described to measure the Hall effect in semiconductors at frequencies between 18 and 24 kmc. The semiconductor sample forms the common narrow wall of two sections of *K*-band wave guide which run perpendicular to each other and to the direction of the dc magnetic field. A modulated microwave signal of approximately 5 mw is fed into one wave guide, and the Hall power is detected in the second wave guide. Leakage is nulled by a wave-guide bridge arrangement. Equations are given which relate the microwave power in the secondary wave guide to the Hall mobility of the sample. As an example, Hall measurements at 20 kmc on 40 ohm-cm *N*-type germanium from 0 to 10 000 gauss are presented.

F2. Study of the Conduction Band of Ge by Piezoresistance Measurements. M. POLLAK, *Westinghouse Research Laboratories* (introduced by R. W. Keyes).—Piezoresistance measurements have been performed on *n*-type germanium with donor densities from 6×10^{15} cm^{-3} to 3×10^{19} cm^{-3} over the temperature range 77°K to 300°K. The results can be interpreted in terms of the usual model for the conduction band in germanium which was formulated on the basis of measurements on high-purity material, provided that statistical degeneracy is taken into account. The density of states required to explain the degeneracy effects corresponds to the four valley model. The absence of any detectable effect caused by electrons in (100) minima shows that these minima are at least 0.11 ev above the (111) minima. Even in the most impure specimens the mobility anisotropy ratio, μ_1/μ_{11}, is not reduced by more than a factor of two.

F3. Pair 1/f Noise in Germanium Filaments.* W. H. FONGER, *RCA Laboratories.*—Semiconductor $1/f$ noise has been ascribed to a $1/f$ generation of electron-hole pairs at surfaces. In particular, many features of transistor and diode $1/f$ noise have been explained by assuming a pair-generation rate with spectral density $\langle dg^2\rangle/df=\psi(f)(p-p_0)^2$ per unit area.[1] This model is now applied to germanium filaments. Such filaments contain small, bulk n-n' (or p-p') junctions which are caused by imperfect melt stirring during crystal growth. Under filament dc electric bias, these junctions inject or extract dc disturbed pair concentrations p-p_0 which in turn excite $1/f$ pair generation at surfaces in accordance with the foregoing equation. dc disturbances p-p_0 also can be created through dc light irradiation. In the experimental work, small, accidental, n-n' junctions were detected quantitatively through their characteristic photovoltaic effects. Then $1/f$ noise was excited through various combinations of dc electric bias and local dc light irradiation. The complicated dependence of the noise on these electric and light parameters is explained by the model above.

* Supported by the Wright Air Development Center.
[1] W. H. Fonger, *Transistors I* (RCA Laboratories, Princeton, New Jersey, 1956), p. 239.

F4. Measurements on Germanium Surfaces "Cleaned" by Argon Bombardment. R. FORMAN, *National Carbon Research Laboratories.*—The surface properties of Ge were explored by means of electrical measurements on single-crystal material "cleaned" by the argon sputtering technique. Field effect and conductivity of the samples were measured in ultra-high vacuum (10^{-9} mm Hg) as well as in different ambients. A modified Bardeen-Brattain cycle was used after the surfaces were "cleaned" to obtain a minimum in the surface conductance. The data indicate that the "cleaned" surfaces are p type and that the edge of the valence band at the surface is close to the Fermi level.[1,2]

[1] J. A. Dillon, Jr., and H. E. Farnsworth, J. Appl. Phys. **28**, 174 (1957).
[2] P. Handler, *Semiconductor Surface Physics* (University of Pennsylvania Press, Philadelphia, 1956), p. 23.

F5. Contact Potential Measurements on Cleaned Germanium Surfaces.* A. B. FOWLER, *IBM.*—The contact potential of the (110) face of the n and p regions of an n-p germanium crystal was measured in a vacuum of less than 10^{-9} mm Hg using a Kelvin bridge technique. The n and p regions were doped so that their resistivities were 0.058 and 0.33 ohm-cm, respectively. If there had been no surface states the difference of the work functions of the two regions would have been 0.34 ev. The clean surface exhibited a difference of 0.002 ($\pm$0.004) ev. The admission of as little as 0.4×10^{-7} mm-min of oxygen increased the difference to 0.013 ev. A difference as large as 0.018 ev was observed after 28×10^{-7} mm-min exposure. After 56×10^{-7} mm-min, the difference decreased to 0.000 ($\pm$0.005) ev. These results may be discussed in terms of several surface state distributions. If each surface atom gave rise to a single acceptor level and all such levels were at the same energy, the state would have to be located at least 0.13 ev below the center of the gap. The n and p regions would both have extremely p-type surfaces with the valence band edge about 0.02 ev from the Fermi level at the surface.

* This work was performed at the Gordon McKay Laboratory, Harvard University, where it was supported jointly by the U. S. Navy, Army Signal Corps, and Air Force.

F6. Length and Resistivity Changes of Germanium upon Low-Temperature Deuteron Irradiation and Annealing.* FREDERICK L. VOOK† AND R. W. BALLUFFI, *University of Illinois.*—Simultaneous measurements of the length and resistivity of germanium single crystals were made upon irradiation and annealing. Specimens were initially irradiated at 25°K with 12-Mev deuterons to a flux of 6.2×10^{16} deuterons/cm^2 and annealed to room temperature. The specimens were then irradiated at 85°K to an additional flux of 9.2×10^{16} deuterons/cm^2 and annealed to 360°K. An expansion of $\Delta L/L=(1.5\pm0.2)\times10^{-21}$ deuteron/cm^2 occurred in both irradiations. The annealing for both runs showed a gradual recovery of the expansion beginning at $\sim$200°K with recoveries of $\sim$50% by 300°K and 85% by 360°K. The resistivity measurements agreed generally with previous results.[1] Resistivity annealing occurred below 138°K. The resistivity decreased irreversibly by a factor of 10^6 between 150°K and 200°K. If the damage is interpreted in terms of point defects, and if the length change recovery is caused by interstitial-vacancy annihilation, then the resistivity changes on annealing below 200°K must be interpreted in terms of the association of defects in various cluster models.

* This work was partially supported by the U. S. Atomic Energy Commission.
† Held U. S. Steel fellowship during major portion of work.
[1] H. Y. Fan and K. Lark-Horovitz, Bristol Conf. Rept., Phys. Soc. (London) (1955).

F7. Distribution of Defects in Electron-Irradiated Germanium. R. L. CUMMEROW, J. N. PIKE, AND A. R. CHERRY, *National Carbon Research Laboratories.*—High-purity n-type germanium samples were irradiated with 2-Mev electrons. These samples originally had a net donor concentration of about 2×10^{13} cm^{-3}. The spatial distribution of radiation induced defects was studied in masked, nonuniformly irradiated samples and also in uniformly irradiated samples. The irradiations were done at room and nitrogen temperatures. Defect distributions were studied by resistance microprobing and small light spot scans in which photovoltage and photoconductivity were measured. At room temperature, the starting material could be converted from n- to p-type, but competing annealing processes made it impossible to introduce more than about 1.3×10^{14} holes cm^{-3}. A study of the p-n junctions between the irradiated and unirradiated regions, by microprobing under reverse-bias conditions, revealed that the junctions were about 400 microns wide. The photovoltaic response was maximum at the junction center. An analysis of the junction potential curve indicates that bombardment-induced levels lie near the center of the forbidden gap. The samples nonuniformly irradiated at nitrogen temperature contained junctions which were poorly defined by photovoltaic and photoconductive measurements. Such measurements on uniformly irradiated samples indicate pronounced inhomogeneities not detectable at room temperature. There is a correlation with pre-irradiated inhomogeneity distributions, as observed at nitrogen temperature. The annealing of such samples at room temperature causes a pronounced shift in junction location and a marked increase in homogeneity.

F8. Wide p-n Junctions Produced in Ge by Electron Bombardment. J. N. PIKE, R. L. CUMMEROW, AND A. R. CHERRY, *National Carbon Research Laboratories.*—The theory of multiple scattering of electrons in solids due to Bethe, Rose, and Smith[1] has been applied to the case of 2-Mev electrons bombarding high-purity n-type Ge. By taking account of the energy dependence of the displacement cross section of Ge atoms, it was found that the transition region between damaged (p-type) and undamaged Ge should be of the order of 500 μ, which is in agreement with potential probe observations. Junction width was insensitive to reverse bias voltage. Photovoltage produced by a chopped light spot was measured as a function of distance from the junction and of temperature (in the range 77 to 290°K). The variation of junction position with temperature was consistent with the assumption of a bombardment-produced acceptor level near

the center of the band gap, the level density decreasing gradually across the transition region. Photovoltaic peak height as a function of temperature was studied. Room-temperature peak photoconductive response to a light spot depended on the direction and magnitude of the applied voltage, an effect of recombination within the wide transition region.

[1] Proc. Am. Phil. Soc. **78**, 573 (1938).

F9. Evidence for Vacancy Clusters in Dislocation-Free Ge Crystals. A. G. TWEET, *General Electric Research Laboratory.*—Ge crystals have been pulled from the melt which contain volumes of the order of cubic centimeters that are free of dislocations, as inferred from counts of the etch pits produced by *CP*4 on (111) surfaces. When the crystals are grown under appropriate thermal conditions, the etching bath attacks the dislocation-free areas more readily than the rest of the crystal, producing depressions as deep as 0.02 cm during a 3-min etch. Heat treatment of the crystal at 800°C for several hours (or for a few minutes in the presence of diffusing Cu) destroys the enhanced etching effect. Adjacent to areas with the enhanced etching rate there commonly occurs a high density of spiral dislocations[1] which break up into ordinary dislocations during the heat treatment. We suggest that these observations may result from the presence of vacancy clusters formed during cooling from the temperature of growth. Thus the enhanced susceptibility to etching occasioned by the presence of the clusters would disappear during heat treatments which either coagulate or dissolve the clusters. Other etching effects and electrical measurements which are consistent with this interpretation will be discussed.

[1] W. Bontinck and S. Amelinckx, Phil. Mag. **2**, 94 (1957).

F10. Anisotropic Mobilities in Plastically Deformed Germanium. R. A. LOGAN, G. L. PEARSON, AND D. A. KLEINMAN, *Bell Telephone Laboratories.*—*N*-type germanium was plastically deformed with crystal orientation chosen so that the edge dislocations introduced were parallel to the axis of bending. A bridge, suitable for Hall effect measurements, containing two mutually perpendicular regions was prepared from the deformed wafer. In one region, the current flow is parallel to the dislocations while, in the other, current flows perpendicular to the dislocations. The Hall constant and conductivity was measured in each region as a function of temperature (12–350°*K*). Electron mobility for current flow parallel to dislocations was the same as that in an undeformed sample whereas the mobility for current flow perpendicular to dislocations was markedly reduced at low temperatures as predicted by Read.[1] The magnitudes of the observed mobilities are in fairly good agreement with the theory although the fraction of volume occupied by the space charge around the dislocations is larger than that considered by Read. The observed temperature dependence of the electron density is in agreement with the theory for a dislocation acceptor level 0.3 ev from the conduction band.

[1] W. T. Read, Jr., Phil. Mag. **46**, 111 (1955).

F11. Photovoltaic Effect Produced by x- and Gamma Rays in Silicon *p-n* Junction Photocells. K. SCHARF, *National Bureau of Standards.*—An investigation has been made of the photovoltaic effect in silicon solar cells exposed to x-rays and gamma rays from Co^{60} and Cs^{137} sources. Open circuit photovoltage (photo-emf) and photocurrent have been measured as a function of exposure dose rate, photon energy, and direction of incident radiation and of photocell temperature. The observed photovoltaic effect shows little inertia and is proportional to the exposure dose rate of the incident radiation. Photo-emf and photocurrent for the same exposure dose rate of radiation decrease with increasing photon energy, i.e., with decreasing absorption. Because of the low Z number of silicon ($Z=14$), photo-emf and photocurrent for equal exposure dose rate show a very small photon energy dependence between 200 kev and 1.25 Mev. The temperature dependence is in agreement with theory. The angular dependence is influenced by the absorption in the housing of the cell but is very small for radiation of high photon energy. Some measurements of dose dependence will be reported.

THURSDAY AFTERNOON AT 1:30

KIMBALL B-11

(J. W. BEAMS presiding)

Invited Papers

G1. Application of Thermal-Conductivity Measurement to the Study of Crystal Imperfections. R. L. SPROULL, *Cornell University.* (30 min.)

G2. X-Ray Spectroscopy of Solids: A New Type of X-Ray Energy-Level Diagram. L. G. PARRATT, *Cornell University.* (30 min.)

G3. $M_{2,3}$ Absorption Spectra of 3*d* Transition Elements. D. H. TOMBOULIAN, *Cornell University.* (30 min.)

THURSDAY EVENING AT 6:30

(Weather permitting.)

Chicken Barbecue at Taughannock Falls State Park

FRIDAY MORNING AT 9:45

Phillips 101

(D. F. HOLCOMB presiding)

Magnetic Resonance; X-Rays; Molecular Spectra

J1. NMR Shifts in Paramagnetic Solutions. R. G. SHULMAN, *Bell Telephone Laboratories.*—Nuclear Magnetic Resonance studies of paramagnetic crystals[1] have shown that indirect hyperfine interactions affect both the frequency and relaxation times of nuclei in essentially diamagnetic ions. It had been suggested by Bloembergen[2] and Purcell that interactions of this sort could explain the NMR shifts observed in paramagnetic solutions. We shall discuss the NMR shifts observed in four different systems which illustrate different types of interactions. These are: (1) the NMR shifts of N^{14} in $Fe(CN)_6^{-3}$, $Mn(CN)_6^{-3}$, and $Cr(CN)_6^{-3}$ which are 0.072%, 0.125%, and 0.005%, respectively, and which arise from the nonvanishing time average of anistropic hyperfine interactions; (2) the large Cl^{35} shifts of 0.35% and 2.06% in saturated solutions of $CuCl_2$ and $FeCl_3$ in concentrated HCl caused by isotropic hyperfine interactions; (3) the negligible Cl^{35} shifts in Gd^{+3} solutions which agree with our observations in fluoride crystals that the 4*f* electrons are purely ionic; and (4) the two separate F^{19} resonances observed in CuF_2 in concentrated HF and the correlation with the shifts measured in single crystal $CuF_2 \cdot 2H_2O$.

[1] R. G. Shulman and V. Jaccarino, Phys. Rev. **108**, 1219 (1957).
[2] N. Bloembergen, J. Chem. Phys. **27**, 595 (1957).

J2. Double Quantum Transitions and Relaxation Times in Electron Spin Resonance of Mn^{++} in MgO. W. V. SMITH, I. L. GELLES, AND P. SOROKIN, *International Business Machines Corporation, Poughkeepsie.*—The Mn^{++} ion as an impurity in cubic MgO has a fine structure constant *a* of only 20 gauss. Furthermore, for small concentrations the line width of the central transition ($M = -\frac{1}{2}$ to $+\frac{1}{2}$) is very small (about 1 oersted). These experimental conditions are favorable for observation of double quanta transitions ($\Delta M = 2$) which occur between nearly equally spaced energy levels at high rf power.[1] The transitions occur at the frequency $(E_m - E_{m-2})/2h$. The transitions $M = -\frac{3}{2} \rightarrow \frac{1}{2}$ and $M = -\frac{1}{2} \rightarrow \frac{3}{2}$ have been observed at both room and liquid air temperatures in an external field of 3400 oersteds. At the lower temperature these lines are observable at an rf field of 0.5 oersted for all variations of angle and fine structure splitting in the 100 plane. They follow qualitative theoretical predictions, decreasing in intensity at angles of maximum splitting. The saturation behavior of first- and second-order transitions has been observed at angles where these lines were well resolved and also at crossover points where the first- and second-order transitions coincide. The interpretations of these results and of the deduced relaxation times will be discussed.

[1] P. Kusch, Phys. Rev. **93**, 1022 (1954); Brossel, Cagnac, and Kastler, J. phys., radium **15**, 6 (1954).

J3. NMR Relaxation in Binary Solutions.* R. W. MITCHELL AND M. EISNER, *A and M College of Texas.*—Spin-lattice relaxation times for hydrogen nuclei were measured as a function of concentration for the following binary solutions: $C_6H_6-CCl_4$, $C_6H_6-CS_2$, $C_6H_{12}-CCl_4$ and $C_6H_{12}-CS_2$. Both the rotational and translational correlation times are found to be proportional to the macroscopic solution viscosity. The rotational and translational contributions to T_1 have been calculated for C_6H_6 and C_6H_{12} from this data. The rotational correlation times are found to be 4.3×10^{12} for C_6H_6 and 4.6×10^{12} for C_6H_{12}, both values referring to the pure solutions. T_1 measurements were also made for both resonance lines in $C_6H_6-C_6H_{12}$ solutions. The contribution of the $C_6H_6-C_6H_{12}$ collisions to the relaxation of both lines has been calculated by subtracting off the rotational and like translational contributions obtained from the previously measured correlation times.

* Supported in part by the U. S. Air Force Office of Scientific Research of the Air Research and Development Command.

J4. Nuclear Quadrupole Relaxation and Chemical Exchange.* MICHAEL RICE,† *Harvard University* (introduced by E. M. Purcell).—Line shape and saturation measurements have been made of both bromine isotopes in 3–6 *M* aqueous NaBr solutions containing up to 1% $(InBr_4)^-$. The relaxation time, for isotope *j*, is decreased according to: $T_{1j}^{-1}(\text{obs}) = T_{1j}^{-1}(0) + k_2 \cdot c_{In}$, where $T_1(0)$ is the relaxation time at zero indium concentration, and $T_1(\text{obs})$ the relaxation time in the same strength solution, with c_{In} moles/liter $(InBr_4)^-$ added; k_2 is shown to be the reaction rate constant for the chemical exchange of bromine between Br^- and $InBr_4^-$, respectively, the environments of small and large quadrupolar interaction. (Similar effects are found to explain excessive line widths of bromide and iodide solutions arising from free bromine and iodine.) Rate constants have been deduced, and these show a large positive "salt effect." The results support the more general chemical exchange theory proposed in reference 1. This research was carried out under the supervision of Professor R. V. Pound.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at Boston University.
[1] H. M. McConnell, J. Chem. Phys. **28**, 430 (1958).

J5. *V*-Type Center Resonance in Neutron-Irradiated LiF.* Y. W. KIM, R. KAPLAN, AND P. J. BRAY, *Brown University.*—*V*-center electron-spin paramagnetic resonances have been reported in LiF which has received x-ray irradiation at low temperatures.[1,2] We have observed the same type of paramagnetic resonance at room temperature in LiF samples which have received approximately 5×10^{17} nvt of neutron irradiation at room temperature. The resonance pattern consists of four families of low-intensity lines which are spread over a range of 2000 gauss on either side of a strong central response[3] at 3.4 kilogauss when the microwave frequency is 9500 Mcps. The positions of these weak lines are conveniently analyzed in terms of their dependence on the angle α between the (100) or (010) direction and the dc magnetic field which is perpendicular to the (001) axis of rotation of the crystals. A preliminary investigation of this angular dependence employing the theory of Kanzig and co-workers[1,3] supports the identification of the observed lines with their R_1 and R_4 families. The intense central resonance[3] prevents observation of their R_2 and R_3 groups.

* Research supported by the U. S. Atomic Energy Commission.
[1] T. G. Castner and W. Kanzig, Report No. 57-RL-1772, General Electric Research Laboratory (July, 1957).
[2] T. O. Woodruff and W. Kanzig, Report No. 57-RL-1827, General Electric Research Laboratory (November, 1957).
[3] Kim, Kaplan, and Bray, Bull. Am. Phys. Soc. Ser. II, **3**, 178 (1958).

J6. Electron Spin Resonance in Irradiated Dicarboxylic Acids. HAROLD C. BOX AND HAROLD G. FREUND, *Rosewell*

Park Memorial Institute.—Paramagnetic resonance studies have been made of the magnetic centers produced by *X* irradiation in the homologous series of compounds represented by $HO_2C(CH_2)_nCO_2H$. Approximately one free radical is produced for each 100 ev of absorbed energy. The resonance spectra indicate that several radical species are formed whose absorptions are superimposed. Deuterated compounds and single crystal specimens have been used to investigate the origin of the hyperfine structure. Although differing in detail, the hyperfine structure in all of the acids studied appears to contain a component attributable to a radical resulting from the dissociation of an alpha-bound hydrogen atom. Except in malonic acid (n equal 1), the unpaired electron interacts with its three nearest-neighbor protons.

J7. Resolving Power Correction in Precision Measurements of Complex Spectra.* J. O. Porteus and L. G. Parratt, *Cornell University.*—An observed spectral curve is always the convolution of the true curve and a resolving power smearing function. In case the resolving power smear is rather large (e.g., width of the spectral window larger than the width of a component in the true curve), it is imperative that the correction procedure be such as to minimize the final uncertainty in each true-curve point. Uncertainties arise because of experimental errors and finite interval spacings in the observed curve and in the smearing function. An optimum correction method is discussed[1] and applied to the case of the x-ray chlorine K absorption spectra in crystalline KCl as an example in which two resolving power functions are treated successively, i.e., instrumental resolving power and then the smearing by the x-ray K state, to arrive at a density-of-states curve of the solid. The method, practical if a digital computer is available, is sufficiently general that it may be applied to many other experimental problems requiring an optimum solution of the convolution integral.

* Supported by the U. S. Air Force through the Office of Scientific Research of the Air Force Research and Development Command.
[1] See also R. N. Bracewell, Proc. Inst. Radio Engrs. **46**, 106 (1958).

J8. New Type of π-Ray Energy Level Diagram.* L. G. Parratt, *Cornell University.*—Each level in the conventional diagram is based on a theoretical ionization state, i.e., a state in which the inner electron has been ejected to "infinity" and all the remaining electrons in the system have assumed adjusted but unique positions. In application, this diagram is confusing on several counts: (1) "infinity" is not a practical reference position, especially in a solid, (2) the ejected electron may remain bound, albeit lightly, to the positive hole it left behind, giving rise to an excitation state (or exciton), and (3) the other electrons in the system may not assume unique positions for a given inner vacancy. The confusion is greatest in solid-state spectroscopy. Some attempts have been made to include the excitation states in the diagram, but then the indicated energy differences are not correct for actual transitions. A new type of diagram, qualitative at the present state of our knowledge, is proposed in which there are *many* different energy states associated with *each* inner electron vacancy.

* Supported by the U. S. Air Force through the Office of Scientific Research of the Air Force Research and Development Command.

J9. Emission Spectrum of the AlS Molecule.* Charles N. McKinney† and K. Keith Innes, *Vanderbilt University.*—A system of red-degraded bands in the region 3700–4800 A has been obtained from a King furnace containing aluminum, sulfur, and argon at 1800°C. Assignment of the bands to a $^1\Sigma^+ - {}^1\Sigma^+$ transition of the AlS molecule has been confirmed by high-dispersion photographs which exhibit an actual resolving power exceeding 150 000. Vibrational and rotational analyses have been made.

* Supported by Naval Ordnance Laboratory (Maryland) and by Research Corporation.
† Monsanto Fellow, 1957–1958.

J10. Free Radical Microwave Spectrometer.* J. J. Gallagher and V. E. Derr, *Radiation Laboratory, The Johns Hopkins University.*—Free radical gaseous spectroscopy in the microwave region has been hindered by the inadequate means of observing the spectra. A spectrometer has been constructed which allows spectra to be observed in the region from 3 cm to 1 mm. The cell consists of a 3-ft glass tube of 3-in. diameter, which is terminated with Teflon or polystyrene windows. Electroformed horns provide the means of passing radiation through the cell. A lens system is used in the millimeter region. Zeeman modulation is provided for detection purposes. The advantages of this system over previous microwave free radical spectrometers are described. Observations on OH and CS have been performed and are discussed. A survey of the characteristics of other free radicals suitable for observation with this spectrometer is presented. The spectra of stable paramagnetic molecules, NO_2, O_2, and NO have been observed in the region from 24 kmc to 150 kmc in order to demonstrate the versatility of the cell.

* This work has been supported by WADC and ARDC.

Friday Morning at 9:00

Olin M

(C. K. Gartlein presiding)

Invited Papers of the Division of Electron Physics

K1. Physics Research and Physics Training in the Soviet Union. G. H. Dieke, *Johns Hopkins University.* (30 min.)

K2. Production of the Ionosphere by Solar Radiation. Herbert Friedman, *U. S. Naval Research Laboratory.* (30 min.)

K3. Sodium in the Upper Atmosphere. T. M. Donohue, *University of Pittsburgh.* (30 min.)

FRIDAY MORNING AT 10:00

Olin R

(D. R. CORSON presiding)

Symposium on Measurements of Meson Production at Cornell University

L1. Photoproduction of Single Neutral Mesons. J. W. DEWIRE, *Cornell University.* (30 min.)
L2. Photoproduction of Single Positive Mesons. W. M. WOODWARD, *Cornell University.* (30 min.)
L3. Photoproduction of Multiple Mesons. GIUSEPPE COCCONI, *Cornell University.* (30 min.)
L4. Photoproduction of $K^+\Lambda_0$ and $K^+\Sigma_0$. A. SILVERMAN, *Cornell University.* (30 min.)

FRIDAY MORNING AT 9:45

Kimball B-11

(W. P. DYKE presiding)

Electron Emission, I

M1. Experiment for the Detection of Polarization in Photoelectrons. H. A. FOWLER,* L. MARTON, AND H. L. QUINN, *National Bureau of Standards.*—Instrumentation has been constructed to test the proposal of Fues and Hellmann[1] for producing polarized electrons by photoemission from a magnetized solid. Photoelectrons from a cathode illuminated by a strong ultraviolet source are accelerated by a focusing gun and high-voltage stages to 130 kev. Mott scattering from gold and aluminum foils can be performed over a range of scattering angles. The detector comprises a ZnS phosphor, quartz light pipe, and 5819 photomultiplier. Continuous photomultiplier output is available for the detection of polarization. Preliminary results from thin-film cathodes will be reported.

* National Science Foundation Postdoctoral Research Associate, 1957–1958.
[1] Fues and Hellmann, Physik. Z. **31**, 465 (1930).

M2. External Photoelectric Emission of Certain Alkali Halides.* J. W. TAYLOR† AND P. L. HARTMAN, *Cornell University.*—In connection with an investigation on the photoconductivity of NaCl and KCl, the external photoelectric emission of these salts has been studied. The measurements have been made ballistically on thick single crystals as well as with dc methods on evaporated films. Like the results already known on some of the other alkali halides,[1] among them CsI and KI, which were repeated in this work, the yields show a sharp rise to quantum efficiencies of over 10%. Taking the sharp rise to indicate a threshold for electron transitions from the valence band to the vacuum level, this comes out to be about 8.3 ev for both NaCl and KCl. The yield for LiF is rather different, exhibiting a slow rise ahead of the sharp rise at 12.5 ev. The energy distribution of emitted electrons from KCl and NaCl shows a maximum at an energy which increases with increasing photon energy. However, for photons of 21 ev this has dropped back to a lower energy, indicating an internal loss of energy for the excited electrons, as has been postulated for CsSb.[2]

* This work supported by the Office of Naval Research.
† Now at Los Alamos Scientific Laboratories.
[1] H. R. Phillip and E. Taft, J. Phys. Chem. Solids **1**, 159 (1956).
[2] Apker, Taft, and Dickey, J. Opt. Soc. Am. **43**, 78 (1953).

M3. Field Emission from Silicon. F. G. ALLEN AND L. A. D'ASARO, *Bell Telephone Laboratories.*—Using the technique described by D'Asaro,[1] field emission patterns have been obtained many times from both [100] and [110] oriented silicon tips. Patterns from high-temperature annealed tips were reproducible in detail after repeated contamination and recleaning and from one sample to the next. The same pattern resulted for tips cut from *n*-type 20 Ω-cm arsenic-doped silicon as for tips cut from *p*-type 5 to 15 Ω-cm boron-doped silicon. Slight changes in the pattern in some cases are believed to be the result of impurities introduced into the silicon. During initial cleaning certain contaminants have remained on the tip even after heating many minutes to within 50° of the silicon melting point. Once the clean surface has been obtained, subsequent contamination by oxygen, nitrogen, or other residual gases is largely removed by heating briefly to 1150°K and is completely removed in 5 sec at 1510°K or above. Silicon appears essentially metallic in field emission dependence on both field and temperature.

[1] L. A. D'Asaro, J. Appl. Phys. **29**, 33 (1958).

M4. Field Emission from Rare Gases on Tungsten. GERT EHRLICH AND F. G. HUDDA, *General Electric Research Laboratory.*—The interaction of argon, krypton, and xenon with a tungsten surface has been studied in the field emission microscope. Adsorption on a liquid hydrogen cooled emitter results in a lowering of the work function; at saturation, Fowler-Nordheim plots yield values of 4.1, 3.3, and 3.1 v, respectively. Changes on adsorption are most pronounced for high-index planes, and the saturation patterns are similar for the three gases, consisting of emitting rings around the 100 poles. The intermediate stages of adsorption differ, however; patterns increase in detail with diminishing atom size and also vary with surface temperature. Three adsorption regimes, brought about by changes in surface mobility of the adatoms, have been isolated for xenon, with the transition between the two high-temperature forms occurring at 72°K. The minimum binding energy of xenon is estimated at 0.3 ev. The work function of the *W* surface is also lowered upon penetration of the lattice by rare gas ions during bombardment. The effects

of this change, as well as of the applied field, upon the stability of the adlayer will be reported.

M5. Direct Proof of Field Evaporation. M. DRECHSLER AND R. VANSELOW, *Fritz-Haber-Institut, Berlin-Dahlem* (introduced by E. W. Müller).—The disintegration of crystals as a result of strong electric fields (field evaporation) had been investigated by means of field-emission microscope observations.[1] Crystal tips are now field evaporated so deep that the change in tip shape can be observed and measured by an electron microscope or a light microscope. Such experiments prove the hypothesis that the removed particles pass the vacuum and do not migrate over the surface to the shank of the tip as in the case of annealing. In order to find out whether the field-evaporated particles are atoms or ions, a second tip was arranged in front of the field-evaporating tip. The field-evaporated particles produce craters on the second tip which can be observed in its field electron image. It was found that the field-evaporated particles are ions. The crater asymmetry enables one to determine the direction of incidence of a single ion.

[1] E. W. Müller, Phys. Rev. **102**, 618 (1956); M. Drechsler, Z. Elektrochem. **61**, 48 (1957).

M6. Extreme Stress Conditions at the Tip Crystal of the Field Ion Microscope.* ERWIN W. MÜLLER, *Pennsylvania State University*.—The tip crystal in a field ion microscope is under a radial stress of 10^{11} dynes/cm^2 or more. If dislocations are absent, this stress does not exceed the strength of W, Re, Mo, Ta, Ir, Pt, Zr, Si, and C and perhaps a few other metals. The limitation for the observation in the FIM is set by field evaporation of individual ionized surface atoms, the rate of evaporation becoming rather fast towards the end of the foregoing list when He ions are used. Since the radial stress can also be considered as a negative pressure of 10^5 atmos, regional phase transitions to a lower density lattice might occur. If dislocations are introduced, the gradient of stress towards the shank may cause slip, since in general the slip planes are inclined to the tip axis. This is not true for rhenium, where the basal plane as the only slip plane was always found to be parallel to the tip axis. Motion of dislocations and slip of parts of the crystal can be observed continuously in high resolution while the stress is made alternating by superimposing an ac component to the dc field. This is a novel method for studying fatigue.

* Supported in part by the U. S. Air Force through the Office of Scientific Research of the Air Research and Development Command.

M7. Evaporation Rate of Oxide Cathodes by π-Ray Emission Spectrometry. M. D. GIBBONS, *General Electric Research Laboratory*.—X-ray emission spectrometry has been used to determine the evaporation rates of barium, strontium, and calcium from (BaSrCa)O cathodes. Although the method cannot distinguish between an alkaline earth metal evaporated as the free metal or as a compound, it does offer the advantage of enabling one to measure small quantities of the alkaline earth metals, evaporated simultaneously from the cathode. The rates were measured from a passive Ni(DH499), 4% W-Ni, and Ti-Ni alloy base metals in a temperature range of 800°C to 1100°C. In the case of the Ti-Ni alloy, the rate was also measured as a function of time. Evaporation products were measured during the conversion of the carbonates. Results from the different base metals differ significantly, especially at low temperatures.

M8. Effect of Crystal Structure Orientation and Primary Electron Beam Direction on Secondary Electron Emission. A. B. LAPONSKY AND N. R. WHETTEN, *General Electric Research Laboratory*.—Measurements of the dependence of secondary electron yield on angle of incidence have been made for cleaved single crystals of MgO. Several crystal orientations and primary electron energies have been investigated. Results show that a series of maxima occur superposed on the gross variation of yield with incidence angle. The angular positions of the maxima show no significant dependence on bombarding energy (wavelength) and hence are not believed to be caused by diffraction phenomena. The positions of the maxima occur at angles that appear to correspond to the alignment of the primary electron beam with close neighbor atom directions in the crystal. For a given crystal the height of the maxima is dependent on the magnitude of the primary electron energy. The origin of the maxima is believed to be associated with the relative rate of energy loss of the primaries upon entering the crystal at different angles.

M9. Temperature Dependence of the Characteristic Energy Loss of Electrons in Aluminum.* LEWIS B. LEDER AND L. MARTON, *National Bureau of Standards*.—From simple considerations one would expect that the change in the characteristic energy losses of electrons in metals with temperature would depend only on the electron density and hence on the coefficient of thermal expansion. Such a dependence would be $\Delta E_f = \Delta E_i[1-(\frac{2}{3})\alpha\Delta T]$, where ΔE_i is the initial loss, ΔE_f the final loss, ΔT the temperature change, and α the coefficient of thermal expansion. We have measured the change in the energy loss in the temperature range from 4°K to 520°K, and find that above room temperature the change in energy loss agrees with the expected dependence. However, below room temperature the energy loss value changes much more rapidly than expected. From the foregoing relationship we expect to observe a change of ~0.1 ev at both liquid nitrogen and liquid helium temperatures. Instead, we find a change of 0.3 ev and 0.6 ev, respectively. A possible explanation based on the variation of the dielectric constant of the metal[1] (and therefore in the electrical conductivity) at low temperatures is being considered.

* This work was in part supported by the U. S. Atomic Energy Commission and by the Free Radicals Research Program of the National Bureau of Standards supported by the Department of the Army.
[1] Marton, Leder, and Mendlowitz, Advances in Electronics and Electron Phys. **VII** (1955).

M10. Influence of Oxygen on the Emission of Light from Solid Nitrogen during Electron Bombardment.* ERWIN M. HÖRL, *National Bureau of Standards*.—Work previously reported[1] on the emission spectra from solid nitrogen[2,3] condensed on a target at 4.2°K during electron bombardment was continued, and in particular the influence of oxygen was studied in detail. The addition of oxygen to nitrogen of high purity affected almost every feature in the emission spectrum in the visible and ultraviolet range by changing the distribution of intensities. The *A* bands,[3,4] which were faint traces in the pure nitrogen spectrum, were intensified very strongly by adding O_2. Experiments were performed to investigate the effect of a surface layer of oxygen on top of a pure nitrogen solid. They showed a remarkable influence of the O_2 layer on the Vegard-Kaplan bands ($^3\Sigma - {}^1\Sigma$ of N_2) emitted by the nitrogen solid under it. The results of these latter experiments will be compared with those obtained by distributing O_2 in the N_2 matrix mentioned in the foregoing.

* This research was performed under the National Bureau of Standards Free Radicals Research Program, supported by the Department of the Army.
[1] E. Hörl, Bull. Am. Phys. Soc. Ser. II, **3**, 28 (1958).
[2] L. Vegard, Nature **113**, 716 (1924).
[3] Am M. Bass and H. P. Broida, Phys. Rev. **101**, 1740 (1956).
[4] L. Vegard, Ann. Physik **398**, 487 (1930).

FRIDAY AFTERNOON AT 1:30

Olin M

(W. G. SHEPHERD PRESIDING)

Electron Emission, II

N1. Conversion of Heat to Electricity by Thermionic Emission. VOLNEY C. WILSON, *General Electric Research Laboratory.*—Thermionic emission furnishes a source of electric charge. An electric potential from the contact difference of two surfaces can be used to drive this charge to a collecting electrode and through an external load. Thus heat that lifts the electrons out of the cathode may be converted into electrical energy. To prevent back current the anode must be kept colder than the cathode. Therefore, the device becomes a heat engine with a hot source of electrons and a cold sink. Methods will be described for maintaining the required contact difference of potential of two surfaces. Close-spaced diodes, gas-filled diodes, electrodes immersed in crossed-electric and magnetic fields, and gridded tubes have been considered for reducing the space charge barrier between the surfaces. A gas-filled thermionic converter has been built which converts 8.3% of the input heat into electricity. The output was 3.1 w per cm² of cathode surface (0.78 v at 4.0 amp per cm² of cathode).

N2. Theoretical Efficiency of the Thermionic Energy Converter. J. M. HOUSTON, *General Electric Research Laboratory.*—A general analysis of the efficiency of the thermionic energy converter is given in terms of V_c and V_a, which represent the potential differences between the top of the potential barrier between the electrodes and the Fermi levels of cathode and anode, respectively. In general, one would like to increase the output voltage of the device, i.e., increase the term $(V_c - V_a)$. However, it can be shown that, for maximum efficiency, optimum values of V_a and V_c exist. For V_a, the optimum is set by the onset of reverse thermionic emission (from anode to cathode). For V_c, the optimum is determined principally by radiation losses. It is concluded that no fundamental reason exists why efficiencies of 30% or more cannot be realized in converting heat to electricity by this method.

N3. High-Vacuum Thermionic Energy Converter. H. F. WEBSTER AND J. E. BEGGS, *General Electric Research Laboratory.*—Calculations and preliminary experimental results indicate that a useful converter of thermal to electrical energy can be made using a high-vacuum thermionic diode. The calculations were based on Langmuir's solution of space charge conditions in a diode in which the cathode emits electrons with a Maxwellian distribution of velocities. Some parameters which are important in determining the performance of the converter are the cathode-anode spacing, difference of cathode and anode work functions, and saturated emission density available from the cathode. The performance of some experimental converters will be presented.

Invited Papers of the Division of Electron Physics

N4. Low Noise Parametric Amplification Using Variable-Capacitance Diodes. W. E. DANIELSON, *Bell Telephone Laboratories.* (30 min.)

N5. Electron-Beam Parametric Amplifiers. T. J. BRIDGES, *Bell Telephone Laboratories.* (30 min.)

FRIDAY AFTERNOON AT 1:30

Phillips 101

(P. DEBYE presiding)

Magnetism; Chemical Physics

P1. Magnetic Susceptibility of Cu, Ag, and Au from R.T. to 973°K. M. GARBER, W. G. HENRY, AND H. G. HOEVE, *National Research Council, Canada.*—A magnetic balance, suitable for temperature-dependent measurements, using a Mauer[1] type balance in an evacuated system and a 12-in. Varian magnet, is described. The pole piece design yields a region about 2.0 cm long in which $B_y \partial B_y/\partial z$ is reasonably constant. The temperature dependence of copper, silver, and gold are compared. The probable error in the relative values of the susceptibilities is not greater than 0.1%.

[1] F. A. Mauer, Rev. Sci. Instr. 25, 598 (1954).

P2. Magnetic Susceptibility of Cu-Ni and Ag-Pd Alloys at Low Temperatures.* E. W. PUGH† AND F. M. RYAN, *Carnegie Institute of Technology.*—The magnetic susceptibilities of copper-nickel alloys with up to 39 atomic percent nickel and silver-palladium alloys with up to 10 atomic percent palladium have been measured by a Gouy method at temperatures between 295°K and 2.1°K. Measurements made on samples of varying degrees of purity, up to 99.999% pure, indicate that all $1/T$ temperature dependences observed in the silver-palladium alloys and in the copper-nickel alloys with up to 27% nickel are the result of impurities and are not an intrinsic property of the alloys. The simple band model of Mott adequately describes the susceptibility of the silver-palladium alloys but fails to predict the large temperature independent paramagnetic contribution of nickel in copper. Exchange energies calculated by the Stoner collective electron method for the copper-nickel alloys, using specific heat and susceptibility data, are somewhat unsatisfactory and suggest the possible existence of Van Vleck temperature independent paramagnetism.

* Supported in part by a U. S. Atomic Energy Commission research contract.

† Now with International Business Machines Research Laboratory, Poughkeepsie.

P3. Magnetocrystalline Anisotropy of Very Small Cobalt Particles. C. P. BEAN, J. D. LIVINGSTON, AND D. S. RODBELL, *General Electric Research Laboratory.*—Torque and ferromagnetic resonance measurements on a single crystal of a copper −2% cobalt alloy have been made at various temperatures to determine the magnetocrystalline anisotropy of small single domain particles of precipitated cobalt. The anisotropy at 4.2°K is found to be independent of particle radius from 21 A to 77 A, lending support to a crystal field model of the origin of anisotropy. A slight variation of anisotropy with particle size was observed at higher temperatures and was related to a variation in saturation magnetization with particle size at these temperatures. Torque and resonance measurements of the anisotropy give identical results at low temperatures but deviate slightly from one another at elevated temperatures.

P4. Nucleation of Ferromagnetic Domains in Iron Whiskers. R. W. DEBLOIS AND C. P. BEAN, *General Electric Research Laboratory.*—Nucleation fields up to 480 oe have been observed for the reversal of magnetization in regions of nearly perfect iron whiskers about 5 μ thick. This is near the theoretical limit $2K_1/M_s$ ($\approx$510 oe for iron) for the coercive force resulting from magnetocrystalline anisotropy. Alternatively, this result may be used to set a lower limit of 4.1×10^5 ergs/cm^3 for the anisotropy constant K_1 for iron at 25°C. Magnetization reversal in iron whiskers of the size tested readily occurs by domain wall motion in fields of the order of 1 oe if the damaged base of the whisker is included in the region over which the reversing field acts. In addition, gross growth defects on the surface are observed to be sites of easy nucleation.

P5. Angular Dissymmetry of Critical Opalescence as a Measure for the Range of Molecular Forces. P. DEBYE, *Cornell University.*—Both a gas in the vicinity of the critical point and a homogeneous mixture of two liquids near the temperature of separation in two phases show strong scattering of visible light. The scattered intensity shows angular dissymmetry which becomes strong and increases with decreasing temperature distance from the critical point. This dissymmetry can be used practically to compare the range of molecular forces with the wavelength of the light notwithstanding the large difference in magnitude.

P6. Evaporation into a Boundary Layer. ERNEST BAUER AND MARTIN ZLOTNICK, *AVCO-RAD.*—We consider a solid or liquid evaporating into a stream of gas flowing across its surface and ask at what rate the material evaporates as a function of surface temperature and of material and gas properties. Chemical reactions are neglected. The immediate application is to the problem of aerodynamic heat transfer in hypersonic flight.[1] We derive one of the boundary conditions to be used in this problem at the interface between the gas and the solid (or liquid). It is possible to extend the analysis to include chemical reactions in the vapor near the surface.

[1] L. Lees, "Convective heat transfer with mass addition and chemical reaction," Third Combustion and Propulsion Symposium, AGARD, NATO, Palermo, Sicily, (March, 1958).

P7. Structure in Ferric Chloride Solutions. G. W. BRADY, *Bell Telephone Laboratories* (introduced by B. W. Batterman).—Measurements of x-ray scattering from ferric chloride solutions in the concentration range from 1.5M to 5M have been made. The radial distributions calculated from these measurements indicate a large degree of local ordering of the ions, with formation of $Fe^{+3}-Cl^-$ complexes. At the highest concentration the $[FeCl_6]^{-3}$ ion appears to be the main species present. As the concentration is lowered, the coordination of the Cl^-s around Fe^{+3} becomes less definite and other species of the general formula $FeCl_n(H_2O)_n$ or $FeCl_n(OH)_n$ appear. The amount of $[FeCl_6]^{-3}$ present is not a linear function of the $FeCl_3$ concentration. The significance of these results and their importance in the study of complex ion formation and equilibria in concentrated ionic solutions are discussed.

P8. Calculation of Effective Ionic Radii of the Elements Directly Following the Lanthanides[1] in the Periodic System. N. EFREMOV, *New York.*—For calculation of the ionic radii of the quadruple group of ions, Hf^{4+}-Ta^{5+}-W^{6+}-Re^{7+}, we use the following general formula: $R_i(X)=n\times K\times P'$, where n is a certain ion; n, principal quantum number; P', constant ("the shortest length") 0.0109677 A; and K, matrix number: $K(Hf)=14$, $K(Ta)=13$, $K(W)=12$, $K(Re)=11$. Hence, $R_i(Hf)=5\times14\times0.0109677$ A $=0.76$ A, and correspondingly $R_i(Ta)=0.71$ A, $R_i(W)=0.65$ A, $R_i(Re)=0.59$ A. These values are in good agreement with those given by A. Fersman.[2] In particular, the near values of the ionic radii of Hf^{4+} and Zr^{4+} on one hand and those of Nb^{5+} and Ta^{5+} on the other explain the classical isomorphism of these pairs of ions in such minerals as zircon (Zr and Hf) and columbite (Nb and Ta).

[1] N. Efremov, Phys. Rev. **93**, 934(A) (1954).
[2] A. Fersman, Selected Works III, 169 (1955).

Post-Deadline Papers, If Any

FRIDAY AFTERNOON AT 1:30

Kimball B-11

(R. R. WILSON presiding)

Nuclear Physics, I

Q1. High-Resolution Neutron Spectrometer Using Capture γ-Ray Detector.* S. DESJARDINS, J. ROSEN, E. MELKONIAN, L. J. RAINWATER, AND W. W. HAVENS, JR., *Columbia University.*—The Columbia University Nevis time-of-flight neutron spectrometer using a 35.4-m flight path and the new 2000-channel analyzer with 0.1 μsec gates has been used to examine levels in Cd, Ta, Ag, and U^{235} up to $\sim$1 kev. Results of analysis for reduced widths, level spacings, and peak cross sections will be presented together with some discussion of the various self-indication and area techniques employed.

* This work was partially supported by the U. S. Atomic Energy Commission.

Q2. Elastic Scattering of 5.6-Mev Neutrons from Carbon.* J. E. BRALEY, AND C. W. COOK, *Convair.*—Energetic neutrons produced from the $D(d,n)He^3$ reaction have been scattered

from a cylindrical carbon block to study the angular distribution of elastically scattered, 5.6-Mev neutrons. The differential elastic scattering cross section for carbon has been obtained for angles in the range of 30° to 150° in increments of 15°. A thin plastic detector was used to discriminate against the 4.43-Mev gamma rays from the carbon sample and other gamma-ray background.

* Performed using the Lockheed Van de Graaf, Palo Alto.

Q3. Angular Distributions of 2.82-Mev Neutrons Elastically and Inelastically Scattered from Bi^{209}.* B. D. KERN, J. SHELTON, AND W. H. SNEDEGAR, *University of Kentucky.*—The angular distributions of 2.82-Mev neutrons elastically and inelastically scattered from Bi^{209} have been measured. Three neutron groups corresponding to the target nuclei being left in the ground state, the 0.895-Mev excited state, and the 1.56-Mev excited state have been resolved with a time-of-flight neutron spectrometer of 3 mμsec effective resolving time. The neutrons were produced through the $D(d,n)He^3$ reaction with 90-kev deuterons from a Cockcroft-Walton accelerator. The ground-state group shows a distribution with angle which is characteristic of the optical model and is nearly identical with that at 2.5 Mev.[1] The two inelastically scattered groups show a definite asymmetry about 90°, with the intensity at 18° being 4.5 times that at 130°, indicating that a considerable fraction of the reactions proceed by a direct interaction process. The 90° cross section for the 0.895-Mev level group is found to be 26 mb/sterad, and for the 1.56-Mev level group, 22 mb/sterad.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] Beyster, Walt, and Salmi, Phys. Rev. **104**, 1319 (1956).

Q4. Analysis of *p-p* Scattering Experiments below 40 Mev.* MALCOLM H. MACGREGOR, *University of California, Radiation Laboratory, Livermore.*—Proton-proton angular distribution measurements at 3.037, 4.203, 9.73, 9.74, 18.2, 19.8, 31.8, and 39.40 Mev have been analyzed in terms of *S*, *P*, and *D* phase shifts. A parametrization method, based on work by Clementel and Villi,[1] has been used at each energy to define a region in the *S-D* plane within which good fits to the angular distribution can be obtained. For each *S-D* pair there are four sets of *P*-wave solutions. Analysis with a search code developed by Noyes[2] shows that *F*-wave contributions are important at 40 Mev. On the other hand, the addition of *F* waves does not improve the least-squares fit at 20 Mev. The multiplicity of solutions can be reduced by accurate polarization measurements. Further restrictions are obtained by studying the predictions of the various nuclear-potential models. A simple model consisting of the second-order asymptotic meson potential extended into a repulsive core has been used to predict the (small) *P* and *D* phase shifts, both in Born approximation and by integration of the radial wave equation.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] E. Clementel and C. Villi, Nuovo cimento **2**, 1165 (1955).
[2] H. P. Noyes and M. H. MacGregor, UCRL-4947 Rev. (1957) (submitted to Phys. Rev.).

Q5. Inelastic Contributions to Elastic Electron Scattering from Helium. H. S. VALK AND P. O. DAVEY, *University of Oregon.*—An estimate is made of the contributions of electrodisintegration and pion production to the elastic scattering cross section for high-energy electrons from helium. It has been shown[1] that such an estimate can be made in first Born approximation if the total nonradiative inelastic cross sections are known. The latter are determined by utilizing expressions recently derived by Muto and Sebe.[2] The results of the calculations indicate that electrodisintegration is the dominant process at present energies (200 Mev–600 Mev) and that it introduces a correction to the elastic cross section of at most a few percent.

[1] H. S. Valk, Nuovo cimento **6**, 173 (1957).
[2] T. Muto and T. Sebe, Progr. Theoret. Phys. (Japan) **18**, 621 (1957).

Q6. Electron Scattering from the Deuteron and the Neutron-Proton Potential.* JOHN A. MCINTYRE AND GEORGE R. BURLESON, *Stanford University.*—Electrons at energies of 400 and 500 Mev have been scattered by deuterons with accuracy higher than that attained in previous measurements.[1] The results have been analyzed using Jankus' static calculation of electron-deuteron scattering.[2] The sizes of the proton and the neutron in the deuteron have been introduced according to the analysis of Yennie, Levy, and Ravenhall.[3] For direct comparison with experimental results, three deuteron wave functions satisfying the usual requirements have been substituted[1] into Jankus' formula. Two of the wave functions are generated by Yukawa-type neutron-proton potentials while the other results from a repulsive-core (Gartenhaus) potential. The effect of the proton size has been eliminated experimentally by taking ratios between the electron-deuteron and electron-proton scattering. The neutron size has been assumed to be negligibly small. Using the analysis of the data outlined in the foregoing, the experiments agree with the repulsive-core deuteron scattering and do not agree with either of the Yukawa deuterons. This result tests only the *S*-state charge distribution of the deuteron.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research, Air Research and Development Command.
[1] J. A. McIntyre and S. Dhar, Phys. Rev. **106**, 1074 (1957).
[2] V. Z. Jankus, Phys. Rev. **102**, 1586 (1956).
[3] Yennie, Levy, and Ravenhall, Revs. Modern Phys. **29**, 144 (1957).

Q7. Precision Determination of First and Second Excited Levels in Tb^{159} and Ho^{165}.* E. L. CHUPP, *University of California, Livermore,* J. W. M. DUMOND, *California Institute of Technology,* AND F. J. GORDON, R. C. JOPSON, AND HANS MARK,† *University of California, Livermore.*—The first and second excited levels in Tb^{159} and Ho^{165} have been observed by bombarding appropriate targets with 3.75-Mev protons from the A-48 accelerator at UCRL, Livermore. The gamma rays resulting from the electric excitation process were observed with a bent quartz crystal spectrograph. In both isotopes, gamma rays were observed from the first excited states as well as cascade gamma rays between the first and second excited levels. Gamma rays at 57.99±0.01 kev and 79.50±0.02 kev were observed from the terbium target and 94.69±0.04 kev and 109.92±0.08 kev from the holmium target. The second excited level in Tb^{159} is at 137.49±0.02 kev, and in Ho^{165} it is at 204.61±0.09 kev. The energies predicted for these levels by the simple rotational interval rule are 139.18±0.02 kev for Tb^{159} and 210.42±0.09 kev for Ho^{165}, showing deviations of 1.69±0.03 kev and 5.81±0.13 kev, respectively, from the measured values.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Now at MIT.

Q8. Effect of Channel Mixtures on *n*-γ Correlations from Stripping Reactions.* S. EDWARDS, JR.,† G. E. OWEN, AND L. MADANSKY, *The Johns Hopkins University.*—Angular distributions of the outgoing particles in some (d,n) and (d,p) reactions have been explained with the Butler stripping theory including the concept of heavy-particle stripping to treat exchange effects.[1] The purpose of this paper is to incorporate the additional channel representing heavy particle stripping into the simple Born approximation theory of *n*-γ or *p*-γ angular correlations[2] for these reactions when they are followed by radiative transitions. The preferred axes of quantization and the correlation function for this channel are in general different[3] from those for the deuteron stripping

channel. Since the relative orientation of the preferred axes for the channels and contributions to the angular distribution from each channel and their interference are functions of the outgoing-particle angle, the total correlation function is different for forward and backward angles. It is also highly sensitive to the angular momentum coupling scheme used in the simple model of the process. Theoretical results for various angles and coupling schemes for the reaction $B^{11}(d,n)C^{12*}(\gamma)C^{12}$ will be given.

* Supported in part by the U. S. Atomic Energy Commission.
† General Motors Fellow in Statistical Physics.
[1] G. E. Owen and L. Madansky, Phys. Rev. **105**, 1766 (1957); O. Ames and G. E. Owen, Phys. Rev. **109**, 1639 (1958).
[2] G. R. Satchelor and J. A. Spiers, Proc. Phys. Soc. (London) **A65**, 980 (1952).
[3] Rask, Ames, Edwards, Madansky, and Owen, Bull. Am. Phys. Soc. Ser. II, **2**, 351 (1957).

Q9. Angular Distribution of the $S^{32}(n,p)P^{32}$ Reaction.* F. L. HASSLER, H. P. EUBANK, AND R. A. PECK, JR., *Brown University.*—The $S^{32}(n,p)P^{32}$ differential cross section has been measured with a proportional counter scintillation counter telescope at 0°, 30°, 60°, and 90° with angular resolutions between 14° and 20°. Angular distributions are determined in intervals of 1-Mev excitation of P^{32}. Low excitations (0–4.5 Mev) for which the levels have predominantly spin = 0 show forward asymmetry peaking at about 20°. Above 4.5 Mev, for which all known levels have spin = 1, the angular distribution shows an abrupt change going over to a peak at 0° and another at 60°, the latter washing out at higher excitations near 8.5 Mev. The interval 8.5- to 9.5-Mev excitation consists mainly of a forward peak at 0°. The total cross section for the excitation range 0–9.5 Mev is about 185 mb in rough agreement with recent activation determinations.[1]

* Supported in part by the U. S. Atomic Energy Commission.
[1] Allen, *et al.*, Phys. Rev. **107**, 1363 (1957).

Q10. (n,p) Cross Sections near $Z = 50$.* H. P. EUBANK, R. A. PECK, JR., AND R. AL-KITAL, *Brown University.*—Forward differential (n,p) cross sections have been measured with a proportional counter-scintillation counter telescope for 14.1-Mev neutrons on the following nuclei: $_{45}Rh^{103}$ $_{47}Ag$(natural) Cd(natural) $_{49}In^{115}$, $_{50}Sn^{116}$, $_{50}Sn^{120}$, and $_{51}Sb$(natural). The measurements were made with an angular spread of about ±20° centered about 0°, and cover the proton energy range 4 Mev to 14 Mev. In all cases the bulk of the yield occurs above 7 Mev, having a very small compound nucleus contribution. A decrease in cross section as a function of Z occurs, reaching a minimum at $Z = 50$ of less than 20 mb and rising abruptly at $Z = 51$ to approximately 200 mb, similar in behavior to the effects of shell closure exemplified in neutron capture cross section near $N = 50$.[1]

* Supported in part by the U. S. Atomic Energy Commission.
[1] D. J. Hughes and D. Sherman, Phys. Rev. **78**, 632(L) (1950).

Q11. Double Electric Dipole Transitions in Light Nuclei. A. G. W. CAMERON, *Atomic Energy of Canada Limited.*—Photonuclear investigations show that in light nuclei a substantial fraction of the $E1$ sum rule limit is exhausted by transitions to a few individual compound states. If there are also strong $E1$ transition probabilities between these compound states and other low-lying levels, then the emission of 2 $E1$ quanta between such low-lying levels can compete with $E2$ transitions. The width (ev) for the double process is $\Gamma(2E1) \approx 2.6\times10^{-6}A^{\frac{2}{3}}E_{if}{}^{7}\Sigma_n g_{in}g_{nf}/\omega_{in}\omega_{nf}$, where E_{if} is the energy difference (Mev) between the initial and final states, g_{in} and g_{nf} are the fractions of the sum rule limit (0.015 A Mev barns) exhausted by transitions between the initial and final states and the common compound states n, and ω_{in} and ω_{nf} are statistical factors. For the 7.65 → 4.43 Mev and 7.65 → 0 Mev transitions in C^{12} and the 6.06 → 0 Mev transition in O^{16}, upper limits on $\Gamma(2E1)$ are 0.03, 7, and 3 ev, respectively. For the last case $\Sigma_n g_{in}g_{nf} < 3\times10^{-7}$, showing that there is remarkably little overlap in the strengths of $E1$ transitions from these two O+ states to all higher states. If there is more overlap for the corresponding states in C^{12}, the double $E1$ process may dominate the radiative decay of the 7.65-Mev state, with important consequences for the 3α process in nuclear astrophysics.

FRIDAY EVENING AT 8:30

Statler Auditorium

(J. W. BEAMS presiding)

S1. Tales of Science and Scientists. P. DEBYE, *Cornell University.*

SATURDAY MORNING AT 9:30

Kimball B-11

(G. COCCONI presiding)

Invited Paper

T1. A Connection between the Shell Model and the Rotational Model of the Nucleus. J. P. ELLIOTT. *University of Rochester.* (30 min.)

Nuclear Physics, II

T2. Total Photoelectric Cross Section at 662 kev. W. FRANK TITUS, *National Bureau of Standards.*—Preliminary measurements of the total photoelectric cross section at 662 kev have been made. A highly collimated beam of gammas from a 500-Mc Cs^{137} source impinges normally upon a thin (~10 mg/cm²) foil mounted on an anthracene crystal. A

NaI(Tl) crystal anticoincidence is placed so as to intercept a large portion of the beam photons Compton-scattered into the backward hemisphere by the anthracene crystal. Pulse-height analysis of those pulses from the anthracene crystal not in coincidence with pulses from the NaI(Tl) crystal reveals the distribution due to photoelectrons from the target. Tests were made for target thickness effects. The beam intensity was measured by means of a 4-in.×5-in. diameter NaI(Tl) crystal. Relative and absolute cross sections for Cu, Ag, and Au are presented in Table I.

TABLE I.

	Relative cross sections		Absolute cross sections	
Element	Experimental	Grodstein[a]	Experimental ×10[24]	Grodstein[a] ×10[24]
Cu	0.114±8.9%	0.111	0.132±10 %	0.128
Ag	1.00	1.00	1.16 ± 5.3%	1.15
Au	10.0 ±2.3%	10.3	11.5 ± 5.4%	11.9

[a] G. W. Grodstein, Natl. Bur. Standards Circular 583 (1957) by interpolation.

T3. Absorption of 1-Bev Gamma Rays.* E. MALAMUD AND J. W. DEWIRE, *Cornell University.*—The total cross section for the interaction of 1-Bev gamma rays in various elements has been measured by an attenuation method using a magnetic pair spectrometer for a detector. Tentative results are

Beryllium	0.1675 barns	±0.0017
Aluminum	1.365	±0.018
Copper	5.934	±0.071
Tin	16.35	±0.11
Lead	39.05	±0.82

The errors quoted are standard statistical errors. There is an additional uncertainty of not more than ½% resulting from various effects which will be described. The results will be compared with measurements at lower energy and with the predictions of theory.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

T4. Possible Experiments for Determination of Beta Interactions. M. MORITA AND R. S. MORITA, *Columbia University.*—Recently we have proposed thirty-three possible experiments to decide the relative strength of scalar *vs* vector interactions and tensor *vs* axial vector interactions in beta decay.[1] For all the proposed experiments, it is necessary to measure the recoil of the nucleus directly or the nuclear resonance fluorescence caused by a gamma ray which follows the beta decay or K capture, in decays involving beta-gamma, beta-gamma-gamma, and K-capture gamma-gamma cascades. We have calculated the intensity and the circular polarization of the resonant gamma ray; this intensity when in coincidence with the other emitted particles; the directional correlations among the beta ray, the gamma ray, and the resonant gamma ray or the nuclear recoil; and the beta-ray spectra in coincidence with the gamma ray and the resonant gamma ray or the nuclear recoil, etc. The negatron decay of Co^{60} has been analyzed in detail. In the Goldhaber, Grodzins, Sunyar type experiment,[2] the circular polarization of the 1.33-Mev gamma ray from Ni^{60} is expected to be 2% left- (23% right-) handed if the beta interaction is axial vector (tensor).

[1] Morita, Morita, and Yamada, Phys. Rev. (to be published).
[2] Goldhaber, Grodzins, and Sunyar, Phys. Rev. **109**, 1015 (1958).

T5. In-Flight Annihilation of Positrons. SAMUEL J. RAFF, *U. S. Naval Ordnance Laboratory and University of Maryland.*—The cross section for in-flight annihilation of positrons with electrons at rest has been measured at 300-, 175-, and 100-kev positron kinetic energy in lead and in aluminum. The method employs a beta spectrometer to focus positrons from Na^{22} on a foil, and the annihilation is detected by the capture of both annihilation quanta in coincidence. In all cases where the positron kinetic energy is much higher than the K-electron binding energy, the agreement with theory is within 6%. At the lower positron energies, particularly in lead, the observed annihilation rate is lower than the calculated rate in the extreme case by as much as 40%. This reduction can be explained in a semiquantitative way as the result of the Coulomb field of the atom.

T6. On the Mass of the Neutral Pion. OTTO HALPERN, *Pacific Palisades.*—Experiments[1,2] on the reaction $p+\pi^-\rightarrow n+\pi^0\rightarrow n+2\gamma$ are generally interpreted as leading to a mass of π^0 equal to that of π^- minus $9m_e$. Here π^0 appears in a real intermediate state of definite kinetic energy. Now if the mass of π^0 should exceed that of π^- diminished by the neutron-proton mass difference, then π^0 could only appear in virtual intermediate states, the absolute value of the momentum of π^0 varying between 0 and approximately $0.93m_\pi C$. The decay of these virtual neutral pions leads again to a Doppler broadening of the γ frequencies which has some similarities with that observed. The sum of the frequencies of 2 quanta simultaneously emitted varies over a small range while it is constant for real pions. The possibility here discussed conflicts with theoretical estimates[3] of pion mass differences; still, it may not be without interest to establish definitely if it is also incompatible with experiment.

[1] Panofsky, Aamodt, and Hadley, Phys. Rev. **81**, 565 (1951).
[2] W. Chinowsky and J. Steinberger, Phys. Rev. **93**, 586 (1954).
[3] R. P. Feynman and G. Speisman, Phys. Rev. **94**, 500 (1954).

T7. Production of Auger Electrons by Negative π Mesons and K Mesons.* ELIZABETH B. CHESICK AND J. SCHNEPS, *Tufts University.*—When a negative particle is captured by an atom, it may produce one or more "Auger" electrons. The rate of production of Auger electrons depends on the mass of the negative particle, and, according to Burhop,[1] in silver and bromine K^- mesons ($m=965m_e$) should produce about 50% more Auger electrons of energy greater than 15 kev than π^- mesons ($m_\pi=273m_e$). We have examined 200 π^--meson stars and 195 K^--meson stars in nuclear emulsion for associated Auger electrons of energy greater than 15 kev. For π mesons we find that 14.5% of the stars have one Auger electron and 3.5% have two. For K mesons 25.1% have one, 5.6% have two, and 1.0% have three. Thus 18% of all π-meson stars and 31.5% of all K-meson stars have one or more associated Auger electrons. Assuming that 54% of all stars are in the heavy elements of the emulsion, we find 33.3±5.6% of π mesons and 58.7±7.5% of K mesons captured in silver and bromine have one or more associated Auger electrons. Hence the increase in production by K mesons over that by π mesons is 76±38%.

* Supported by the U. S. Atomic Energy Commission and the Research Corporation of America.
[1] E. H. S. Burhop, *The Auger Effect and Other Radiationless Transitions* (Cambridge University Press, Cambridge, 1952), p. 170.

T8. K^+-Meson Interactions in Nuclear Emulsions.* D. FOURNET DAVIS AND M. F. KAPLON, *University of Rochester.*—The interactions of K^+-mesons of energies up to 250 Mev are being studied. A stack of emulsion consisting of 80 pellicles, each 400 μ thick and 25 cm×9.3 cm in area, was exposed to the "seperated" K^+-meson beam at the Berkeley Bevatron. The stack has the advantage that it is large enough to stop K^+ mesons of 250 Mev. This allows the stopping particles to be identified by their characteristic decay modes. The energy dependence of the cross section and of the ratio, charge exchange/inelastic scatter, will be presented. These results will be based on the data from about 30 meters of track. Thanks are due N. Kwak for helping in the analysis of the data.

* This work was supported in part by the U. S. Atomic Energy Commission and by the Office of Scientific Research, Air Research and Development Command, U. S. Air Force.

T9. Antiproton-Proton Cross Sections at 133–333 Mev.* CHARLES A. COOMBES, BRUCE CORK, WILLIAM GALBRAITH,† GLEN R. LAMBERTSON, AND WILLIAM A. WENZEL, *University of California, Berkeley.*—In an experiment at the Bevatron to study interactions of antiprotons in hydrogen, a parallel-plate electrostatic magnetic velocity spectrometer was used to achieve partial separation of antiprotons from π mesons. Identification of the antiprotons was made by a time-of-flight scintillation-counter system. The antiprotons then entered a liquid hydrogen target which was completely surrounded by plastic scintillation counters. Total elastic scatttering and charge-exchange cross sections are given in Table I for each of four energies. Angular distributions for the elastic scattering will be presented.

TABLE I.

T (Mev)	σ_{Total} (mb)	σ_{Elastic} (mb)	$\sigma_{\text{Ch. exch.}}$ (mb)
133 ± 13	170 ± 12	78 ± 12	10_{-4}^{+9}
197 ± 16	156 ± 9	69 ± 9	11_{-4}^{+9}
265 ± 17	127 ± 12	58 ± 9	8_{-4}^{+6}
333 ± 17	117 ± 6	53 ± 5	8_{-4}^{+6}

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Commonwealth Fellow. On leave of absence from AERE, Harwell, England.

T10. Mass of the A^0-Hyperon. E. B. BRUCKER, F. ANDERSON, AND A. PEVSNER,* *The Johns Hopkins University,* AND J. LODGE,† *Goucher College.*—A program has been instituted to measure the Q value of the reaction $\Lambda \rightarrow \pi^- + p$. A G-5 stack was exposed at the Bevatron to a K^- beam of 300 Mev/C. The pellicles are now being area scanned. Many two-pronged events with a π^- and proton, both stopping in the emulsion, have been found and measured. Corrections to the raw Q values are now being applied. The results will be presented at the meeting.

* Supported in part by the U. S. Air Force Office of Scientific Research of the ARDC.
† Supported in part by the National Science Foundation.

T11. Cosmic-Ray Increases Associated with Solar Flares.* L. C. TOWLE AND J. A. LOCKWOOD, *University of New Hampshire.*—Data from a standard IGY neutron monitor on Mount Washington, New Hampshire, has been examined for possible increases associated with solar flares following the method of Firor.[1] No increases $\geq 0.25\%$ have been found for for the years 1956 and 1957. The locations of the 0400 and 0900 impact zones have been determined for both the standard centered dipole approximation and the modified centered dipole approximation suggested by Simpson *et al.*[2] The effect of flare activity on the mean daily cycle has been studied for this period. Possible reasons for the variation of this result from that obtained by Firor will be discussed.

* Supported by the Geophysical Research Directorate, Air Force Cambridge Research Center.
[1] J. Firor, Phys. Rev. **94**, 1017 (1954).
[2] Simpson, Fenton, Katzman, and Rose, Phys. Rev. **102**, 1648 (1956).

SATURDAY MORNING AT 9:30

Olin M

(A. V. PHELPS presiding)

Invited Papers of the Division of Electron Physics

U1. The Behavior of Plasmoids. W. H. BOSTICK, *Stevens Institute of Technology.* (30 min.)
U2. Problems of Generating High Circulating Currents of Relativistic Electrons. S. H. NEDDERMEYER, *University of Washington.* (30 min.)

SATURDAY MORNING AT 9:30

Phillips 101

(P. L. HARTMAN presiding)

Solid-State Physics, Mostly Crystals

V1. Effect of Anisotropy on the Temperature Dependence of Elastic Constants. RICHARD F. GREENE, *Westinghouse Research Laboratories.*—We suggest than an important part of the temperature dependence of the elastic constants of perfect crystals arises from the elastic anisotropy itself without reference to the features of any model of the interaction between the atoms. The intrinsic effect of the anisotropy is introduced via the local oscillatory rotations produced in a crystal by transverse acoustic vibrations. The elastic properties belonging to different directions are thereby mixed in proportion to the temperature. A linear temperature dependence of the elastic constants and a partial averaging out of the anisotropy results. Application is made to the elastic constants of β brass.

V2. Screened Electron-Phonon Interaction. H. EHRENREICH, *General Electric Research Laboratory,* AND M. H. COHEN, *Cambridge University, England.*—A "bare" electron-phonon interaction potential V_P is interpreted in metals as arising from the motion of ionic cores,[1] and in semiconductors as the interaction when there are no free carriers. V_P is modified by the presence of free carriers in both metals[1] and semiconductors. Screening effects have already been found to be important for optical modes in semiconductors.[2] In the present quantum mechanical treatment the Liouville equation is solved in conjunction with Poisson's equation for a given Fourier component $V_P(\omega,q)$ of V_P corresponding to frequency ω and wave number q. The self-consistent potential $V(\omega,q)$ can be expressed in terms of a complex longitudinal dielectric

constant $\epsilon(n)=\epsilon_1(n)+i\epsilon_2(n)$, depending on the carrier density n in the form $V(\omega,q)=[\epsilon(o)/\epsilon(n)]V_P(\omega,q)$. Adiabatic perturbation of the electrons gives rise to $\epsilon_1(n)$. Scattering of the electrons by the self-consistent field gives rise to $\epsilon_2(n)$. The equation $\epsilon_1(n)=0$ is the plasma dispersion relation when the lifetime of a plasmon is infinite. A nonzero value of $\epsilon_2(n)$ indicates finite lifetime. In metals $\epsilon_2(n)$ vanishes for large ω/q and becomes finite abruptly at the plasma cutoff. In semiconductors it is possible to have $|\epsilon(n)|\approx 0$ for phonons q that contribute appreciably to electron scattering.

[1] J. Bardeen and D. Pines, Phys. Rev. **99**, 1140 (1955).
[2] H. Ehrenreich, Bull. Am. Phys. Soc. Ser. II, **2**, 313 (1957).

V3. Polarized Luminescent Emission from KCl:Tl at Low Temperatures. CLIFFORD C. KLICK AND W. DALE COMPTON, *U. S. Naval Research Laboratory.*—At temperatures near that of liquid helium, polarized emission is observed from isolated thallium centers in KCl:Tl with a degree of polarization $P=0.2$. The polarization does not appear at liquid nitrogen temperatures, and it is not dependent on the concentration of thallium. Arguments may be given which make it seem unlikely that this effect is due to crystal strain or the proximity of the luminescent center to other imperfections. It is possible that there is a splitting of the levels of the excited state of thallium due to the Jahn-Teller effect which would give the ion in the excited state the ⟨100⟩ symmetry necessary to explain the observed emission. Comparison is made of the experimental results with the theory of the Jahn-Teller effect developed by Van Vleck and by Öpik and Pryce. Difficulties with this interpretation are discussed. In contrast to the thallium centers, polarization is not found for luminescent emission from F centers in KCl at temperatures near liquid helium.

V4. Configuration Coordinate Model for KCl:Tl Including Spin-Orbit Interaction. P. D. JOHNSON AND F. E. WILLIAMS, *General Electric Research Laboratory.*—The effect of spin-orbit interaction on the $^3P^0$ and $^1P^0$ states of the Tl^+ in KCl now has been included in the configuration coordinate model. The present model is in accord with the spectral characteristics explained by the earlier model[1] and with the oscillator strengths for impurity absorption.[2] It has, however, additional distinguishing features. The potential energy curve for the lower excited state has two minima which account for the 3050 A and 4750 A emission bands. The transition from the upper excited state to the ground state should result in a new emission band near the long wavelength absorption band at 2470 A. With intense excitation at 77°K in a narrow spectral range near 1960 A, which results in excitation only to the upper excited state, the predicted emission has been found. This emission is strongly absorbed for most experimental arrangements. The emission and reabsorption provide one mechanism for proceeding from the upper to the lower excited state. The existence and characteristics of the new emission provide confirmation of the model, particularly of the quantitative effect of spin-orbit interaction.

[1] e.g., P. D. Johnson and F. E. Williams, J. Chem. Phys. **21**, 125 (1953).
[2] Williams, Segall, and Johnson, Phys. Rev. **108**, 46 (1957).

V5. Abstract without a Name. H. W. ETZEL AND D. A. PATTERSON, *U. S. Naval Research Laboratory.*—The optical absorption spectra of crystals of NaCl, KCl, and KBr from various sources (Harshaw, Optovac, and USNRL) have been measured from the visible region to 170 mμ. Bands appear at 185 mμ in NaCl, at 204 mμ in KCl and at 214 mμ in KBr. The position of these bands satisfies an Ivey relation, $\lambda=691d^{0.95}$, indicating the same center may be responsible for the observed absorptions in the three alkali halides. In NaCl and in KCl the band is enhanced manyfold by the addition of alkali hydroxide to the Kyropoulos melt. KCl and KCl:OH crystals were grown in an argon atmosphere in both gold and platinum crucibles. The results were the same with both crucible materials. When NaCl crystals are additively colored, a hydride ion absorption (U band) appears. The U-band absorption in NaCl is proportional to the 185 mμ absorption band in the crystal before additive coloration. The F-band absorption produced by x-rays in NaCl is also proportional to the 185 mμ band absorption prior to irradiation. The effect of divalent ions upon the 185 mμ band will also be discussed.

V6. Conductivity Induced in CdS Crystals by 30- to 60-kev Electrons. C. E. BLEIL, D. D. SNYDER, AND Y. T. SIHVONEN, *General Motors Research Staff.*—CdS crystals were irradiated with 30- to 60-kev electrons, and the resulting conductivity, σ, was measured. A plot of $\Sigma(\sigma/\text{unit of energy flux})$ *vs* E (incident particle energy) shows that Σ increases with increasing E. This is contrary to what has been reported[1] for incident beam energies below 30 kev. A beam current of 5×10^{-9} amp at 50 kev was sufficient to cause the CdS crystals to luminesce. The wavelength of the luminescence depends upon the electron beam intensity. For lower beam intensities, the luminesced color is red with a maximum at 6850 A while at higher intensities the color is green with a maximum at 5260 A. An explanation of the observed conductivity and the two luminesced colors is given based on the band model and two electron-hole recombination processes.

[1] Ryvkin *et al.*, Zhur. Tech. Zizicki **24**, 961 (1954).

V7. Optical Constants of KCl in the Fundamental Absorption Region Derived from Reflectivity Measurements. J. R. NELSON AND A. H. SCHAINBLATT, *Convair-San Diego*, AND P. L. HARTMAN, *Cornell University.*—The optical constants $n(E)$ and $k(E)$, $(N=n-ik)$, are calculated as a function of photon energy E for KCl. In addition oscillator strengths are computed for the three principal peaks of the fundamental absorption centered at 7.8 ev, 9.6 ev, and 12.7 ev, respectively. The complex index of refraction $N(E)$ is derived from experimental normal incidence reflectivity data[1] by a mathematical analysis previously described for the exciton absorption of NaCl.[2] Oscillator strengths are determined from $N(E)$ by using the dispersion relation of Hopfield.[2,3] Because this analysis is programmed on an IBM 704 computer, greater precision is attained for the optical constants of KCl than was the case for NaCl.[2]

[1] Hartman, Nelson, and Siegfried, Phys. Rev. **105**, 123 (1957).
[2] J. R. Nelson and J. J. Hopfield, Bull. Am. Phys. Soc. Ser. II, **3**, 126 (1958).
[3] J. J. Hopfield, Bull. Am. Phys. Soc. Ser. II, **3**, 125 (1958).

V8. Status of Observable Intrinsic Photoconductivity in NaCl and KCl.* P. L. HARTMAN AND J. W. TAYLOR,† *Cornell University.*—An extended search for the photoconductivity to be expected in pure NaCl and KCl has been made, partly to verify reported measurements[1] and partly to locate the conduction band relative to the valence band. The search has been carried out for photon energies of from roughly 7 ev to 21 ev. Carrier currents on many of the experiments as small as 10^{-16} amp could be detected. Measurements are made difficult by the copious primary external photoemission observed. Means were taken to eliminate the effect of this. A weak internal current observed in the near ultraviolet with semitransparent electrodes is understood in terms of known observations.[2] To date, no true intrinsic photoconductivity has been identified. Possible reasons for this may lie in a very high rate of trapping near the surface or in the existence of a high surface electric field, together with the extremely high absorption coefficient. Although various geometries have been used, the work is being continued in still possible variations of the experimental conditions.

* This work supported by the Office of Naval Research.
† Now at Los Alamos Scientific Laboratories.
[1] J. N. Ferguson, Phys. Rev. **57**, 1089(A) (1940).
[2] A. von Hippel *et al.*, Phys. Rev. **91**, 568 (1953).

V9. Photocapacitative Effects in Additively Colored Alkali Halide Crystals. A. J. GLASS AND D. KAHN, *RIAS, Incorporated.*—Illumination of alkali halide crystals containing ionizable centers produces electrons in the conduction band changing the crystal impedance. A determination of the crystal impedance at sonic frequencies using current blocking electrodes allows, in principle, the measurement of the density and mobility of electrons in the conduction band.[1] Measurements of the crystal impedance at room temperature as a function of frequency from 2 cps to 1 kc have been made on additively colored KBr crystals in various stages of bleaching. It has been found that unbleached additively colored crystals show a frequency dependance of the impedance in agreement with that expected from a linear space-charge theory.[2] Measurements using bleached crystals show the same deviation from the predictions of the linear theory as found by others.[1] The reason for this deviation and the results obtained with unbleached crystals will be discussed.

[1] J. R. Macdonald, J. Chem. Phys. **23**, 275 (1955).
[2] J. R. Macdonald, Phys. Rev. **92**, 4 (1953).

V10. Electron Excitation of Bilayer Fluorescent Screens. L. R. KOLLER AND H. D. COGHILL, *General Electric Research Laboratory.*—Bilayer cathodoluminescent screens consisting of a thin transparent film of manganese-activated zinc sulfide on top of a transparent film of silver-activated zinc sulfide have been constructed and their luminescent behavior investigated. The ratio of the relative intensity of the cathodoluminescence from the two layers is measured as a function of the energy of the incident electron beam. Depending upon screen thickness and beam voltage in the range between 10 and 20 kv, this may vary from total beam energy absorbed in the first layer to more than 99% of the beam energy absorbed in the second layer. A relation for the relative luminescent intensities based on the Thompson-Whiddington law of electron penetration and Koller and Alden's work on scattering is derived and found to be in good agreement with experiments. The electron scattering compensates for the high absorption at the end of the range. This results in relatively high brightness for the thin upper film at values of energy corresponding to maximum range greater than the film thickness while at still greater values of voltage most of the energy is absorbed in the underlying layer.

V11. Radiation Enhancement of dc Electroluminescence and Light Amplification in Powder Phosphors. W. A. THORNTON, *Westinghouse Electric Corporation.*—Enhancement of electroluminescence by superposition of radiation and dc fields is observed in certain copper-activated zinc-sulfide powder phosphors, containing chlorine, which are both strongly electroluminescent and photoconductive. dc electroluminescence emission is increased by factors of more than ten by addition of the radiation; under these conditions the photoluminescence with zero field is about equal to the dc electroluminescence in the absence of incident radiation. Radiant power gain exceeds unity over a range of irradiation intensity of 0.1 to 1.0 microwatts/cm² at 365 mμ. Enhancement occurs at excitation wavelengths of 440 mμ and shorter. Spectral changes to shorter wavelengths, with applied field, indicate that the dc electroluminescence is enhanced by the radiation. The general nature of the effect is indistinguishable from that reported by Cusano and Williams.[1,2] and the data are explainable by a photosensitive resistance in series with the emitting region of the phosphor crystal.[3]

[1] D. A. Cusano, Phys. Rev. **98**, 546 (1955); **106**, 604 (1957).
[2] D. A. Cusano and F. E. Williams, J. phys. radium **17**, 742 (1956).
[3] H. F. Ivey, Bull. Am. Phys. Soc. Ser. II, 3,273 (1958), following abstract.

V12. Photoconductivity as a Factor in Enhancement of Luminescence by Electric Fields. H. F. IVEY, *Westinghouse Electric Corporation.*—Destriau[1] first observed enhancement of luminescence by electric fields; his observations, however, appear unrelated to electroluminescence (EL) excitation. Subsequently Cusano,[2] Woods,[3] and Thornton[4] observed enhancement, which is related to EL, in a variety of materials. Williams[5] interpreted Cusano's observations as "radiation-controlled EL" with the control residing in the potential barrier responsible for EL. Loebner[6] has also discussed the importance of photosensitive barriers in EL and electrophotoluminescence. An alternative explanation presented here assumes that the radiation control is asserted, not as a direct effect in the barrier, but as an indirect process involving regulation, by the photoconductive bulk of the phosphor, of the potential across the barrier. The situation is thus identical in principle to "light amplifiers" employing separate photoconductive and EL elements.

[1] M. Destriau, Comptes rend. **238**, 2298 (1954); G. Destriau *et al.*, J. Electrochem. Soc. **102**, 682 (1955).
[2] D. A. Cusano, Phys. Rev. **98**, 546 (1955); **106**, 604 (1957).
[3] J. Woods, J. Electronics and Control **3**, 531 (1957).
[4] W. A. Thornton, Bull. Am. Phys. Soc. Ser. II, **3**, 273 (1958), preceding abstract.
[5] F. E. Williams, Phys. Rev. **98**, 547 (1955).
[6] E. E. Loebner, Symposium, Polytechnic Institute of Brooklyn (September, 1955).

SUPPLEMENTARY PROGRAMME

SP1. Radiation Enhancement of ac Electroluminescence of Powder Phosphors. W. A. THORNTON, *Westinghouse Electric Corporation.**—Enhancement of electroluminescence by superposition of radiation and ac fields is observed in strongly electroluminescent ZnS:Cu,Cl, Zn(S,Se):Cu,Cl, ZnSe:Cu,Cl, and ZnS:Cu,Mn,Cl phosphor powders, emitting from blue to red, at frequencies from 10 to 10^5 cps and at radiation intensities from 0.1 to 100 microwatts/cm². Enhancement occurs at excitation wavelengths of 440 mμ and shorter. The combined emission observed is as much as 30% greater than the sum of the individual emissions resulting from field and radiation. The added light is spectrally similar to the electroluminescence and not to the photoluminescence. The effect is not observed in a strongly electroluminescent ZnS:Cu phosphor which contains no chlorine and shows negligible photoconduction. The enhancement is explainable by a photosensitive resistance in series with the emitting region of the phosphor crystal.[1]

* To be given at the end of Session V if the Chairman rules that time permits.
[1] H. F. Ivey, Bull. Am. Phys. Soc. Ser. II, 3, 273 (1958), abstract V12, this issue.

Author Index to Papers Presented at the Ithaca Meeting

Adawi, I.—A6
Al-Kital, R.—Q10
Allen, F. G.—M3
Anderson, F.—T10
Balluffi, R. W.—F6
Baranger, Elizabeth—C8
Barredo, Joseph G.—C11
Barut, A. O.—C2
Bauer, Ernest—P6
Bean, C. P.—P3, P4
Beggs, J. E.—N3
Benedek, G. B.—A2
Bleil, C. E.—V6
Bostick, W. H.—U1
Box, Harold C.—J6
Bradley, R. C.—B2
Brady, G. W.—P7
Braley, J. E.—Q2
Bray, P. J.—J5
Bridges, T. J.—N5
Brucker, E. B.—T10
Bryan, R.—C6
Burleson, George R.—Q6
Cameron, A. G. W.—Q11
Cherry, A. R.—F7, F8
Chesick, Elizabeth B.—T7
Chiu, Hong-Yee—C7
Chupp, E. L.—Q7
Cocconi, Giuseppe—L3
Coghill, H. D.—V10
Cohen, M. H.—V2
Compton, W. Dale—V3
Cook, C. W.—Q2
Cook, G. R.—E6
Coombes, Charles A.—T9
Cork, Bruce—T9
Cummerow, R. L.—F7, F8
Danielson, W. E.—N4
D'Asaro, L. A.—M3
Davey, P. O.—Q5
Davis, D. Fournet—T8
DeBlois, R. W.—P4
Debye, P.—P5, S1
Derr, V. E.—J10
Desjardins, S.—Q1
de Swart, J.—C6
DeWire, J. W.—L1, T3
Dieke, G. H.—K1
Dixon, J. R.—A9
Donohue, T. M.—K3
Drechsler, M.—M5
Drumheller, C. E.—A4
DuMond, J. W. M.—Q7
Edwards, S., Jr.—Q8
Efremov, N.—P8
Ehrenreich, H.—A11, V2
Ehrlich, Gert—M4
Ehrman, Joachim B.—C10
Eisner, M.—J3
Elliott, J. P.—T1
Enright, D. P.—A9
Etzel, H. W.—V5
Eubank, H. P.—Q9, Q10
Fineman, Morton A.—E5
Fonger, W. H.—F3
Forman, R.—F4
Forte, M.—E1
Fowler, A. B.—F5
Fowler, H. A.—M1
Freund, Harold G.—J6
Friedman, Herbert—K2
Galbraith, William—T9
Gallagher, J. J.—J10
Galligan, J. M.—A4
Garber, M.—P1
Gärtner, W. W.—F1
Gelles, I. L.—J2
Gerjuoy, Edward—B3
Gibbons, M. D.—M7
Glass, A. J.—V9
Gordon, F. J.—Q7
Gray, Ernest P.—E3
Gray, P. V.—A11
Greene, Richard F.—V1
Gürsey, Feza—C3
Halpern, Otto—T6
Ham, Frank S.—A1
Hambleton, G. E.—F1
Hartman, P. L.—M2, V7, V8
Hassler, F. L.—Q9
Hasted, J. B.—B1
Havens, W. W., Jr.—Q1
Henry, W. G.—P1
Hickmott, T. W.—E8
Hirsh, Merle N.—E2
Hoeve, H. G.—P1
Hörl, Erwin M.—M10
Houston, J. M.—N2
Hudda, F. G.—M4
Innes, K. Keith—J9
Ivey, H. F.—V12
Johnson, P. D.—V4
Jopson, R. C.—Q7
Kahn, D.—V9
Kaplan, R.—J5
Kaplon, M. F.—T8
Kern, B. D.—Q3
Kerr, Donald E.—E2
Kim, Y. W.—J5
Kleinman, D. A.—F10
Klick, Clifford C.—V3
Koller, L. R.—V10
Lambertson, Glen R.—T9
Laponsky, A. B.—M8
Leder, Lewis B.—M9
Livingston, J. D.—P3
Lockwood, J. A.—T11
Lodge, J.—T10
Logan, R. A.—F10
MacGregror, Malcolm H.—Q4
Malamud, E.—T3
Mandansky, L.—Q8
Mark, Hans—Q7
Marshak, R.—C6
Marton, L.—M1, M9
McIntyre, John A.—Q6
McKinney, Charles N.—J9
Melkonian, E.—Q1
Mellen, W. R.—C9
Meshkov, Sydney—C8
Miller, C. G.—E1
Mitchell, R. W.—J3
Morita, M.—T4
Morita, R. S.—T4
Müller, Erwin W.—M6
Myers, Ira T.—E4
Neddermeyer, S. H.—U2
Nelson, J. R.—V7
Ogawa, M.—E6
Owen, G. E.—Q8
Parratt, L. G.—J7, J8, G2
Patterson, D. A.—V5
Pearson, G. L.—F10
Peck, R. A., Jr.—Q9, Q10
Petrocelli, Americo W.—E5
Pevsner, A.—T10
Pike, J. N.—F7, F8
Pinnick, H. T.—A3
Pollak, M.—F2
Porteus, J. O.—J7
Pugh, E. W.—P2
Quinn, H. L.—M1
Raff, Samuel J.—T5
Rainwater, L. J.—Q1
Rice, Michael—J4
Rodbell, D. S.—P3
Rosen, J.—Q1
Ryan, F. M.—P2
Sakurai, J. J.—C4
Samson, J. A. R.—E6
Schainblatt, A. H.—V7
Scharf, K.—F11
Schneps, J.—T7
Shelton, J.—Q3
Shulman, R. G.—J1
Signell, P. S.—C6
Sihvonen, Y. T.—V6
Silverman, A.—L4
Smith, W. V.—J2
Snedgar, W. H.—Q3
Snyder, D. D.—V6
Sorokin, P.—J2
Spitzer, W. G.—A7
Sproull, R. L.—G1
Suh, Kiu S.—C5
Taylor, J. W.—M2, V8
Thornton, W. A.—V11, SP1
Titus, W. Frank—T2
Tomboulian, D. H.—G3
Towle, L. C.—T11
Tweet, A. G.—F9
Valk, H. S.—Q5
Vanselow, R.—M5
Varela, J. O.—A8
Vook, Frederick L.—F6
Webster, H. F.—N3
Weissler, G. L.—E6
Wenzel, William A.—T9
Whetten, N. R.—M8
Williams, F. E.—V4
Wilson, Volney C.—N1
Woodward, W. M.—L2
Zemel, Jay N.—A10, A8
Zlotnick, Martin—P6

Room Reservations for Ithaca Meeting

To: A. L. Johnson
Department of Physics
Rockefeller Hall
Ithaca, New York

Please reserve space for (Name or names)

.....

.....

.....

.....

for nights of June 18 (Wednesday) ....., June 19 ....., June 20 ....., June 21 ..... I prefer:

Dormitory single ($3.00 per night) .....

Dormitory double ($5.00 per night) .....

Motel .....

Please note that no room in Cornell Residential Halls has a private bath, and children cannot be accommodated in these dormitory rooms. Please also note that motel space is limited. If you wish to share a double room with another person, please give his name and address

.....

.....

Probable arrival by auto ....., train ....., plane ....., bus .....

(A confirmation of reservation will be sent as soon as possible and will instruct you where to go on arriving in Ithaca.)

(To be mailed to A. L. Johnson, Department of Physics, Rockefeller Hall, Ithaca, New York)

Chicken Barbecue—Taughannock Falls State Park

6:30 P.M., Thursday, June 19

Please reserve ..... tickets at $1.50 each.

I have transportation ..... Please reserve a bus seat at $.50 (round trip) .....

I enclose my check for .....

Name .....

(Reservation *must* be made before the meeting. Tickets will be distributed at the registration desk.)

(To be mailed to A. L. Johnson, Department of Physics, Rockefeller Hall, Ithaca, New York)

Ladies' Programme

I plan to attend the tea Thursday .....

Please reserve ..... bus seat(s) for the excursion on Friday ($2.25 each). I enclose check for .....

Name .....

Second Announcement of the Vancouver Meeting

The 1958 Summer meeting in the West will be held in Vancouver, British Columbia, on August 26, 27, and 28. Full instructions as to how to reserve accommodations for this meeting, and a number of interesting features of the meeting, have been published in the just-previous (Washington) issue of the Bulletin, to which our readers are referred. Deadline is June 27, and abstracts are to be sent to Professor W. A. Nierenberg, Local Secretary for the Pacific Coast, University of California, Berkeley 4, California.

Preliminary Announcement of the 1958 Thanksgiving Meeting

The 1958 Thanksgiving meeting will be held at Chicago, in the buildings of the University of Chicago, on November 28 and 29. The Hotel Windermere, at 1642 East 56th Street (Chicago 37, Illinois) will accommodate our members until its rooms are fully booked and will place later applicants in neighboring hotels. Deadline for abstracts is September 26. Abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

MEETINGS AND DEADLINES FOR THE SEASON 1958–1959

Place	*Meeting dates*	*Deadline date*
Ithaca, New York	June 19–21	past
Vancouver, British Columbia*	August 26–28	June 27
Chicago	November 28–29	September 26
Los Angeles*	December 29–31	October 17
New York	January 28–31, 1959	November 14
Austin, Texas	March 6–7	January 9
Cambridge, Massachusetts	March 30, 31, April 1	January 16
Washington, D. C.	April 30, May 1–2	February 20
Milwaukee, Wisconsin	June 18–20	to be decided
Hawaii	August 27–29	to be decided

* Abstracts for the Vancouver and Los Angeles meetings are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 P.M. Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; one must be an original, the other may be an original or a carbon copy. Carbon copies will not be accepted in lieu of originals: they smear. *Abstracts must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. *If we receive an abstract typed on two pages, we print only its first page.* Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It now becomes an expensive business to make any change in an abstract, even the smallest, after the abstract has gone to press. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

Communication from the Treasurer

For the information of the members the Treasurer presents the following statements condensed from the report for the year 1957 of Conroy, Smith & Co., auditors, as presented to the Council at Washington on April 30, 1958.

SHIRLEY L. QUIMBY, *Treasurer*

OPERATING INCOME AND EXPENSES ALLOCABLE TO THE YEAR ENDING DECEMBER 31, 1957

Income:				
Membership dues			$195 675.35	
The Physical Review				
Income:				
Nonmember subscriptions	$127 464.67			
Published articles	141 090.55			
Sale of back numbers	4 269.87			
Membership subscriptions	64 378.66	$337 203.75		
Expenses:				
Cost of production and distribution:				
6920 pages to 7024 member and 3080 nonmember subscribers	$294 061.97			
Editorial office	40 986.92	$335 048.89	$ 2 154.86	
Net receipts from dinners and registration fees			4 271.15	
Interest on bonds and savings accounts			6 820.99	
Net gain on sale of securities			189.69	
Buckley Physics Prize Award Trust			250.00	
Miscellaneous			450.98	$209 813.02
Expenses:				
Office of the Secretary and Treasurer:				
Salaries		$ 16 737.48		
Payroll taxes and retirement fund contributions		581.84		
Traveling expenses of Officers of Society		1 999.43		
General office expenses		7 073.54	$ 26 392.29	
American Institute of Physics—collecting dues and subscriptions			14 733.74	
"*Bulletin*"—Cost of printing and mailing		23 170.68		
Editorial mechanics—A.I.P.		3 178.65		
		26 349.33		
Deduct—Income from subscriptions		5 507.66	$ 20 841.67	
Reviews of Modern Physics				
Income:				
Member and nonmember subscriptions	$ 30 425.11			
Published articles	1 367.68			
Sale of back numbers	3 644.50	$ 35 437.29		
Expenses:				
Cost of production and distribution:				
856 pages to 911 member and 8182 nonmember subscribers	$ 46 028.54			
Editorial office	1 438.91	$ 47 467.45	$ 12 030.16	
Cost of membership and reduced rate subscriptions in excess of amounts collected therefor:				
The Review of Scientific Instruments		$ 1 642.50		
The Journal of Chemical Physics		4 077.00		
Journal of Applied Physics		8 389.00	$ 14 108.50	
Contribution to Institution of Electrical Engineers for *Physics Abstracts*			35 332.00	
Contributions to American Institute of Physics:				
For maintenance and support—10% of dues collected		$ 19 882.56		
For building development fund		18 807.77	38 690.33	$162 128.69
Net income from operations of 1957				$ 47 684.33

Balance Sheet as of December 31, 1957

Assets

Cash in banks:			
Checking account		$173 306.80	
Saving accounts		78 492.89	
Custodian account		9 513.05	$261 312.74
Securities—at cost:			
$50 000. United States Treasury, 2¼%, due December 1959–62	$50 836.37		
26 000. United States Treasury, 2¼%, due November 15, 1961	25 025.00		
10 000. United States Treasury, Series F, due April 1959	7 400.00		
14 000. United States Treasury, Series K, 2.76%, due May 1967	14 000.00		
30 000. United States Treasury, Series K, 2.76%, due February 1968	30 000.00		
15 000. American Telephone and Telegraph Co. Debentures 3¼%, due July 1990	14 615.65		
15 000. General Electric Co. Debentures, 3½%, due May 1976	14 709.40		
15 000. Niagara Mohawk Power General Mortgage, 3¼%, due May 1, 1986	14 521.90		
15 000. Standard Oil Co. of New Jersey, Debentures, 2¼%, due July 15, 1974	13 715.63	$184 823.95	
Common Stocks:			
15 shares International Business Machines Corporation	4 459.65		
140 shares Standard Oil Company of New Jersey	6 861.75	11 321.40	$196 145.35
Accrued interest receivable on investments			262.50
Deferred charges:			
Cost of membership and reduced rate subscriptions to various journals for year 1958 in excess of amount collected therefor			10 283.50
			$468 004.09

Liabilities and Surplus

Accounts payable:			
American Institute of Physics, Inc.		$ 20 240.68	
Institution of Electrical Engineers		5 332.00	
Division of Chemical Physics		689.61	
Teacher's Insurance and Annuity Association		489.98	
Director of Internal Revenue		665.92	$ 27 418.19
Deferred Credits:			
Membership dues—year 1958		$148 586.31	
Subscriptions received from members applicable to issues of journals to be published subsequent to Dec. 31, 1957:			
The Physical Review	$50 281.07		
Physics Abstracts and *Engineering Abstracts*	6 862.95		
Bulletin	2 714.20	$ 59 858.22	$208 444.53
Surplus at January 1, 1957		192 302.65	
Less deferred charge for *The Physical Review* 30-year Cumulative Index transferred to general funds		7 845.61	
		184 467.04	
Add: Net income—year 1957		47 684.33	$232 141.37
			$468 004.09

The 1958 Membership List

The 1958 Membership List went to press on March 15, and the addresses given therein are those on record in the office of the Society at that date. Members who move to new addresses are admonished to notify the post office of these, for the sake of their friends and also of the Society (which must pay for the return of Journals sent to addresses from which the addressees have tracelessly vanished).

Current addresses of the Society's members are on file in the office of the Secretary and Treasurer, and at the American Institute of Physics, 335 East 45 Street, New York 17, New York.

Announcement of a New Journal of the American Physical Society

The Physical Review will no longer carry "Letters to the Editor." Beginning with the issue dated July 1, these will be published in a supplemental semimonthly journal tentatively called ***Physical Review Letters***. By the use of offset printing the Letters will appear in about two to three weeks after receipt instead of the present six to ten weeks. The new *Physical Review Letters* will also print copies of the abstracts of future Physical Review articles.

Physical Review Letters initially will be sent gratis to all subscribers of *The Physical Review*. However, beginning January, 1959, a subscription price will be charged of $5 for members of the American Physical Society and $10 for nonmembers. At that date the publication charge in *Physical Review Letters* will be set at $30 instead of the present $25 per page.

The aim of *Physical Review Letters* is to improve communication among physicists, thereby speeding up the flow of ideas, increasing the interaction of results on related work, and reducing duplication of effort. It will make important results available promptly to all physicists and not merely to the privileged few whose names happen to appear on mailing lists for preprints.

Such a fast-publishing journal may become very popular with authors and could soon grow beyond reasonable bounds. It is therefore our intention to maintain the same strict standards for *Physical Review Letters* as are now in operation for Letters to the Editor. We expect that on the average only about fifteen letters will be acceptable for each issue. "Letters" will be accepted only if they contain important new discoveries or cover topics of high current interest in rapidly changing fields of research. Contributions that do not conform to these requirements do not deserve the very special handling given "Letters" and, no matter how short they may be, should be submitted for publication as Articles in *The Physical Review*. "Letters" must be self-contained in that readers should be able to understand the physics of the contribution—i.e., the procedure followed and the arguments used. We shall reject all "Letters" which *merely* claim results, announce future publications, or advertise papers published elsewhere. We shall also try to discourage the publication of a research program in a series of "Letters" instead of in a comprehensive article.

We have never adhered strictly to the size limitation of "Letters" (600 words) but we prefer that they be less than a printed page (1000 words) and contain no more than two figures. Contributions of excessive length cannot be accepted as "Letters."

Since speedy publication allows no time for thorough refereeing, the Editor is likely to make mistakes and to include occasionally "Letters" of minor importance or below our usual standards. Such occurrences cannot be used as a precedent to require the editor to accept similar "Letters" later on.

To assure speedy publication it is absolutely essential that manuscripts reach us in well-edited form. We have no time to perform a library search to complete faulty references, to locate references in the text, to correct errors in equations, to define undefined symbols, or to identify unclearly written symbols (s or S, κ or k or K, etc.). Figures should be in india ink with the lettering and symbols (also in india ink) large enough so that they are readable after reduction of the figure to three-inch width. Improperly prepared manuscripts will be returned, thereby being delayed in publication.

As in the past, "Letters" must be submitted in duplicate. From now on we request authors of each Article submitted to *The Physical Review* to enclose a duplicate copy of the abstract of their paper.

Dr. George L. Trigg is the assistant editor for *Physical Review Letters*.

Circulation and subscriptions will be handled by the American Institute of Physics, 335 East 45 Street, New York 17, New York.

S. A. GOUDSMIT
Managing Editor

Erratum Pertaining to Abstract MA3 of the 1958 New York Bulletin (Series II, Volume 3, No. 1)

MA3, by F. J. Belinfante. We regret that the first part of reference 1 of this abstract contained a misprint and that the subsequent erratum [Bull. Am. Phys. Soc. Ser. II, 3, 245 (1958)] also contained the same misprint. The reference should read "A Positon Theory without 'Holes' (August, 1953), pp. 26–27."

Proceedings of the American Physical Society

Minutes of the 1958 March Meeting at Chicago

IN the history of the American Physical Society, "Chicago meeting" and "Thanksgiving meeting" are terms so nearly interchangeable that it comes as an anomaly to report on a Chicago meeting that was held in March. To be precise, the first of the 1958 Chicago meetings (there is to be another) was held on Thursday, Friday, and Saturday, March 27, 28, and 29. This convention set three records: the largest registration figure ever attained in March, though not by much (1088 against last year's 1083); the largest number of ten-minute papers ever submitted in March, and by a larger margin over the past record, 260 against 224; and by far the largest meeting of ours every held in Chicago. The University of Chicago met nobly the unprecedented challenge, and the staff that managed our convention deserves all the more praise because it was new to the job, the Institute for the Study of Metals having succeeded to the Institute for Nuclear Studies as our host. Special thanks are due and gratefully offered to E. A. Long, Chairman of the Local Committee, and Ruth Patterson his secretary on whom the principal burden devolved; and thanks also to Dorothy Johnson, who placed at their disposal her invaluable experience in the similar task of previous years.

The great size of the meeting was due, of course, to its triple character as principal annual meeting of our Divisions of Solid-State Physics, High-Polymer Physics, and Chemical Physics. The relatively young Division of Chemical Physics increased its activity; that of High-Polymer Physics pursued the even tenor of its way; that of Solid-State Physics provided, as usual, the bulk of the papers. So many symposia were arranged by the three Divisions that they got in another's way, and raised the question whether in the future they should be somewhat fewer. The Secretary of the Division of Solid-State Physics is making a study of the distribution of the registrants among fields of interest, and perhaps the results will be available for this or a later issue of this Bulletin. All other topics in physics than those of the three Divisions were represented by one single session of ten-minute papers. Hitherto we have adopted the policy of inviting from the locality of the meeting a wide variety of papers extending over other fields of physics; it was set aside on this occasion because another Chicago meeting is coming along in November.

The banquet of the Society was held on Friday evening in the Quadrangle Club. The Chancellor of the University of Chicago—L. A. Kimpton—and A. W. Lawson gave the after-dinner speeches. The attendance, as usual, was pitifully small (155): it is always a cause of wonderment that so many of our members fast on Friday evening. There was a "social affair" in the Quadrangle Club on Thursday afternoon: we are told that by contrast this was an event with standing-room only, and none too much of that.

The Council held a brief meeting on March 28. It elected candidates to Fellowship and to Membership in the Society; the list follows.

KARL K. DARROW, *Secretary*

Elected to Fellowship on March 28, 1958: Nicholas G. Anton, David B. Beard, Robert T. Beyer, Philip J. Bray, Gerald E. Brown, Jules R. de Launay, Antonio Ferri, and Robert W. Morse.

Elected to Membership on March 28, 1958: Adolf A. Abrahamson, Denys O. Akhurst, John M. Baker, David S. Barmby, *Gene A. Barnes, Klaus H. Behrndt, Aristid D. Berk, Richard E. Berry, *Robert W. Bierig, James F. Black, John A. Blaylock, Claude C. Bouchiat, *Charles D. Bowman, Charles R. Bowman, Edward L. Boyd, John N. Bradley, Werner W. Brandt, William D. Brennan, *Walter E. Bron, *Wilbur K. Brown, *Robert L. Burkholder, *Allan I. Carlson, *Robert L. W. Chen, Frank L. Chiaretta, Soon Tahk Choh, Richard A. Clark, *Robert K. Cole, Donald Coles, *David H. Coward, Charles S. Cox, *Mary E. Cunningham, Harvey A. Dahl, Robert V. de Vore, Frederick A. Dieter, James A. Dyer, Donald S. Elkort, David J. Epstein, *Glen E. Everett, Patricia Failla, *Daniel H. Filson, *David E. Fisher, William E. Flannery, Richard K. Fox, Hyland M. Fulton, *Jacek K. Furdyna, *C. Gerald Gardner, M. R. Garnier, Milton Genser, Gary R. Giedd, *Floyd D. Goar, Andrew R. Gobat, Gordon E. Gross, Otto J. Guentert, *Gerald Guralhik, Robert J. Haislmaier, Joseph Halperin, *Robert G. Hamerly, Roy J. Happel, Jr., *Howard R. Hart, *Charles W. Hartman, *Eugene B. Herman, *Paul A. Herzberg, *Michael W. Haus, John C. Helmer, *Robert Hight, Jr., *Lewis C. Himmell, *Eiko Kiroike, *James P. Hollinger, *Jan S. Holmstrom, *Gerald Horwitz, Francis J. Howard, *Dwight T. Hoxie, William B. Hugle, Howard F. Ilson, *Thomas C. James, G. Jancovici, Claude E. Jones, Jr., George R. Jones, *Milton N. Kabler, *Claude Kacser, *Ford Kalil, C. R. Kannewurf, Samuel N.

Karp, Morris Katzman, J. V. Richard Kaufman, *Eldon L. Keller, *T. W. B. Kibble, Frank E. Kinard, Richard K. Kirby, Robert W. Kiser, *Richard R. Kofler, Joseph Konijn, *Victor Korenman, *Donald E. Kraft, *David W. Krautkopf, *James I. Kriner, Walter E. Kunz, *Robert A. Laff, *Richard D. Lamb, *Rober H. Lambert, Gottfried Landwehr, William W. Lang, Russell G. Langlois, *Orvel Wayne Larsen, Victor W. Laurie, *Herbert A. Leopold, Leonard S. Levitt, *Jack Lifsitz, Temple A. Love, *Oliver G. Ludwig, *John T. MacQueen, John R. Manning, David L. Matthews, *Donald M. Mattox, Kathryn A. McCarthy, William C. McCorkle, Jr., C. Gene McCormick, Russell C. McRae, Frank R. Meeks, *Rolland A. Missman, *Virgil D. Mochel, *Ralph A. Mollison, John V. Morgan, *Lorne B. Mortara, *Samuel J. Moss, *William J. Mullin, *Richard D. Murphy, *Robert Neiman, William R. Niehaus, *Armond N. Nirdlinger, Willie Ocasio-Cabanas, Adnan M. Odok, Fred Ordway, Larry O. Oswald, *Simon Paluszkiewicz, Robert L. Parker, *Jogesh Chandra Pati, *Richard J. Pendergast, *Irving E. Pengeroth, W. T. Peria, Louis Peselnick, *Robert L. Peterson, Horst A. Poehler, Paul E. Poppert, Charles S. Porter, *Robert J. Pressley, Derek J. Prowse, *Thomas A. Rabson, William A. Ranken, *Alexander J. Rassey, *Dale Carney Ray, *L. Willard Richards, William E. Richeson, Jr., Gerald Rickayzen, *Russell L. Robinson, Jonathan R. Roehrig, Ralph J. Roode, Eugene J. Rosen, Daniel E. Rosner, Radha Raman Roy, *Robert Ruch, Arthur W. Ruff, Jr., David E. Sawyer, *John H. Scandrett, H. M. Schey, Fredric V. Schossberger, *Donald P. Schulz, *Kenneth Schwartz, *Thomas A. Scott, Gerald W. Sears, J. Edwin Sees, Ruth Seiwatz, Benjamin Senitzky, James R. Shackleton, Jack N. Shearer, *Arden Sher, *E. Brooks Shera, *John R. Shewell, *Frank T. Shively, *Fred C. Shure, Kenneth M. Sinnott, *Charles R. Smith, *Henry P. Smith, William A. Snell, Harry E. Spencer, Joseph A. Staples, III, John L. Stewart, John O. Stoner, Arnold A. Strassenburg, *Herbert L. Strauss, Edwin F. Taylor, William E. Thompson, *Nils Tongring, Archie B. Treadwell, Norman J. Veach, Friedrich O. Vonbun, Glen Wade, *Peter Waldstein, *Leslie K. Wanlass, R. Lee Watkins, *James C. Watson, George C. Weiffenbach, Michael S. Wertheim, David M. Wetstone, George R. White, *William J. Whitesell, *Robert C. Whitten, Jr., Richard Williams, *Walter E. Wilson, Wendell B. Wilson, *Wendell S. Winn, *Sanford E. Wolf, R. Woodley, Robert E. Worsham, William V. Wright, Jr., *William M. Yen, Ronald Zielonka, Aubrey P. Altshuller, J. Milton Andres, Philip N. Eisner, *Yoon Suk Koh, *Alan T. Moffet, and Louis R. Testardi.

Errata Pertaining to Abstracts D5, L2, LA12, and Z9 of the 1958 Chicago Bulletin (Series II, Volume 3, No. 2)

D5, by T. Azuma, F. T. Kokoszka, D. R. Cartwright, and J. D. Kurbatov. In line 9, "2.11" should read "2.13." In line 12. "2.11" should read "2.13." In line 13, "2.958" should read "2.964(?)." In line 13, the paragraph beginning with the words "The angular" should be deleted, ending on line 17 with the words "3.6%." In the last line "by MIT group" should be added to the end of the sentence.

L2, by Martin Karplus. The name of the author should be Martin Karplus instead of Dean Karplus. A corresponding correction should be made in the index.

LA12, by R. S. Allgaier. In line 2, "and University of Maryland" should be added to the by-line. In line 17, instead of "the maximum ratio is 2" read "the maximum ratio is 4."

Z9, by Jerome Rothstein. In lines 15 and 16, instead of "A quantitative measure of the unifying of theory" read "A quantitative measure of the unifying function of theory."

Minutes of the Tenth Anniversary Meeting of the Division of Fluid Dynamics Held at Lehigh University, Bethlehem, Pennsylvania, November 25, 26, and 27, 1957

THE 1957 meeting of the Division of Fluid Dynamics was held at Lehigh University, Bethlehem, Pennsylvania, November 25–27. The arrangements for the meeting were made by the Programme Committee consisting of Walker Bleakney, R. J. Emrich, F. N. Frenkiel (*Chairman*), L. S. G. Kovasznay, and G. B. Schubauer and by the local Organizing Committee consisting of C. W. Curtis, R. J. Emrich (*Chairman*), and R. G. Jahn. The scientific programme included 5 invited and 55 contributed papers. The 255 registered participants attending the meeting included 227 from out of town.

As usual at the Divisional meetings, an important part of the scientific discussions was conducted during informal meetings for which appropriate opportunities were arranged. A reception offered on Sunday evening at Hotel Bethlehem, where most participants were staying, was most helpful in renewing or establishing contacts. On Monday morning the participants were welcomed at the Packard Laboratory auditorium by M. D. Whitaker, President of Lehigh University. All scientific sessions were held in this auditorium, and the lobbies and corridors contributed as much to active exchange of views and information. A buffet dinner on Monday evening offered another opportunity for discussions which were not limited to culinary appreciations.

The Tenth Anniversary Banquet of the Division took place at Hotel Bethlehem on Tuesday evening. Those who attended will long remember the Pennsylvania Dutch Dinner and *Der Fuder-Tzettel* (menu) prepared at this occasion. Dean F. E. Myers welcomed the participants, and the dinner was followed by an address given by Joseph Kaplan on the contributions of the International Geophysical Year to the physics of fluids.

This largest meeting of the Division in its ten years of existence was closed by an informal gathering on Wednesday evening.

F. N. FRENKIEL, *Chairman*
Programme Committee
Division of Fluid Dynamics

MONDAY MORNING AT 9:30

(G. B. SCHUBAUER presiding)

A1. The Science of Fluids. R. J. SEEGER, *National Science Foundation.* (30 min.)

A2. Some New Methods and Results for Cellular-Type Stability Problems. W. H. REID, *Yerkes Observatory* (introduced by S. Chandrasekhar).—An approximate method of solving the high-order differential equations arising in problems of hydrodynamic and hydromagnetic stability is described. The method is based upon the use of a suitable set of orthogonal functions which satisfy *four* boundary conditions, i.e., which vanish, together with their first derivatives, on the boundaries. The simplicity and accuracy of the method is demonstrated by applying it to the Bénard problem for which an exact solution is known and for which some further exact results are given. The stability of viscous flow in a curved channel is solved by this method with results which confirm and extend the earlier results of Dean. For a channel formed by two concentric cylinders, between which the spacing, d, is small compared with the radius of the inner cylinder, R_1, the motion is found to become unstable when the parameter $\mathrm{Re}(d/R_1)^{\frac{1}{2}}$ exceeds a value of about 36; the pattern of motion which then sets in is of the cellular type but with a marked asymmetry. The application of this method to stability problems governed by the Orr-Sommerfeld equation is also briefly discussed.

A3. Cross-Stream Wavelength of Boundary Layer Transition. JOHN R. WESKE, *University of Maryland.*—A theory is presented concerning the mechanism producing, at an early stage of transition in the boundary layer, a regular three-dimensional pattern. Relations for secondary vorticity, for the case of rotational yet nonviscous flow, are used to derive quantitative relationships for the cross-stream wavelength of this pattern, for uniform and for retarded free flow. The results obtained are linked to the Taylor-Görtler theory of instability along curved walls.

A4. Apparent Mass of an Object Moving through Superfluid Helium.* J. M. REYNOLDS, B. J. GOOD, AND W. J. SCHULTIS, *Louisiana State University.*—Current theories of the superfluid properties of liquid helium assume that the superfluid component of the liquid is nonviscous, incompressible, and has only curl free motion. Quantum-mechanical considerations[1,2] indicate that these assumptions are reasonable. It was first shown by Stokes[3] that the effect of such a fluid on the motion of an object through the fluid is to give to the object an apparent additional mass. In the experiment reported here, the apparent additional moment of inertia of a very delicate torsion pendulum was measured while immersed in liquid helium at various temperatures below the λ point. At the lower temperatures (below 1.5°K) where the helium is almost entirely superfluid, the additional moment of inertia agrees well with value calculated for a perfect fluid.

* Supported by the Office of Ordnance Research, U. S. Army.
[1] R. P. Feynman, Phys. Rev. **94**, 262 (1954).
[2] Lee, Huang, and Yang, Phys. Rev. **106**, 1135 (1957).
[3] G. G. Stokes, Trans. Cambridge Phil. Soc. **8**, 105 (1843).

A5. Relative Stability Criteria for Nonlinear Hydrodynamics. W. V. R. MALKUS AND G. VERONIS, *Woods Hole Oceanographic Institution.*—A mathematical model of a physical problem with fixed boundary conditions may in general have more than one solution. If the entire class of solutions is known, we may ask, "Which one of the solutions is stable relative to disturbances of the forms of the remaining solutions?" If the answer to this question is unique, we will have found the relizable physical situation; if it is not, a broader class of disturbances may be necessary to resolve the remaining degeneracy. In two-dimensional shear flow and in the Rayleigh convection problem we have established a simple integral expression as the relative stability criterion. Interpreted physically, it states that for the preferred motion the rate of release of potential into kinetic energy minus the rate of dissipation by its fluctuations is a maximum. From the solutions to the linear stability problem for convection one can generate an infinite number of approximate, finite amplitude solutions. With symmetrical boundary conditions application of the principle indicates that the most stable horizontal cellular plan form is a pattern of squares rather than hexagons as generally supposed.

A6. Series Expansion of Distribution Functions in Multicomponent Fluid Systems. EMMANUEL MEERON,* *The University of Chicago and Stanford Research Institute.*—Coefficients in expansions of distribution functions in multicomponent systems in powers of particle number densities are derived by mathematical induction from multicomponent generalizations of the one-component equations.[1] Corresponding expansions of potentials of average force are derived, using new multivariate analogs of certain relations from the theory of cumulants. The results include one-component expansions[2] as special cases. The new expansions were used to derive radial distribution functions and pair potentials of average force in systems of charged particles,[3] somewhat analogous to the original expansions, with the Debye-Hückel potentials of average force appearing in the coefficients instead of the original Coulombic pair potentials, and with certain correction terms derivable by a simple combinatory rule. An explanation of the appearance of the Debye-Hückel potentials is presented, and the significance of the results for systems involving only non-Coulombic forces and for the derivation of more exact potentials of average force is discussed. Possible further developments are suggested.

* Now at Poulter Laboratories, Stanford Research Institute.
[1] J. G. Kirkwood and Z. Salzburg, Discussions Faraday Soc. **15**, 28 (1953).
[2] J. E. Mayer and E. Montroll, J. Chem. Phys. **9**, 2 (1941).
[3] E. Meeron, J. Chem. Phys. **28**, 630 (1958).

A7. New Method of Measuring Diffusion Coefficients of Gases as a Function of Temperature and Concentration.* A. A. WESTENBERG AND R. E. WALKER, *Applied Physics Laboratory, The Johns Hopkins University* (introduced by H. L. Olsen).—The axial decay of a trace gas injected from a "point" source into a laminar stream of a second gas having uniform velocity and temperature has been used to determine $D_{\mathrm{He}-\mathrm{N}_2}$ over a temperature interval 300–600°K and atmospheric pressure. This technique has been critically studied and shown to be valid.[1] Present precision is about $\pm 2\%$. The method is especially suited for studying temperature and concentration dependence. Since the trace gas concentration is very low ($<2\%$), reversal of the gases permits study of the maximum concentration dependence of D. This concentration effect is more pronounced when the molecular masses are very different. Reversals of $\mathrm{He}-\mathrm{N}_2$ and $\mathrm{Co}_2-\mathrm{N}_2$ have been investigated—the former over a temperature interval 300–400°K and the latter at room temperature. These experiments show that theory is qualitatively but not quantitatively correct. For $\mathrm{He}-\mathrm{N}_2$, reversal gave diffusion coefficients about 9% different whereas only 3% is predicted; for $\mathrm{CO}_2-\mathrm{N}_2$ the difference was within the experimental error.

* This work was supported by the Bureau of Ordnance, U. S. Navy.
[1] A. A. Westenberg and R. E. Walker, J. Chem. Phys. **26**, 1753 (1957).

A8. Wall Effects in Cavitating Hydrofoil Flow.* HIRSH COHEN, C. D. SUTHERLAND, AND YIH-O TU, *Rensselaer Polytechnic Institute* (introduced by J. Mayo Greenberg).—A linearized version of the Roshko cavity flow model is used to obtain the effects of solid channel walls on cavitating hydrofoils. The formulation is in terms of two-dimensional flow, but includes any shape hydrofoil within the scope of the linear theory and any location of the foil between the walls. The case of the flat plate foil is considered in numerical detail. For the foil midway between walls, the lift coefficient decreases as the chord-wall height ratio increases. However, for constant cavitation number, the decrease is small for large changes in chord-wall height ratio. At the same time, for small values of cavitation number, the change in cavity length may be large. Thus for experiments in which the cavity length is of minor interest, the cavitation number may serve as a model number. As the cavity length becomes infinite, the "blockage" cavitation number is obtained and the lift coefficient assumes a minimum value for each value of chord-wall height ratio.

* Work sponsored by the Mechanics Branch of the Office of Naval Research.

MONDAY AFTERNOON AT 2:30

(H. W. EMMONS presiding)

B1. Effects of Pressure Waves in a Gas on the Motion of Small Regions of Different Density.* GEORGE RUDINGER AND LOWELL M. SOMERS, *Cornell Aeronautical Laboratory, Inc.*—A spark discharge in an air stream produces a column of hot ionized gas the motion and distortion of which can be observed either by schlieren photography or by direct photography of subsequent sparks which follow the ionized path of the original spark.[1] The first of these techniques yielded flow velocities in a shock tube about 20% too high if the "tagged" column interacted with pressure waves. If the spark was discharged in a steady flow, no deviations were found. These observations could be qualitatively explained by the buoyancy of the hot column in a gravitational field equivalent to the acceleration caused by the pressure waves. A gas bubble of known density could be obtained by the interaction of shock waves with small jets of different gases directed across the duct. This technique seems to be suitable for quantitative evaluations. Schlieren spark and streak photographs of such interactions will be shown.

* Work started under Cornell Aeronautical Laboratory's internal research program and continued under the auspices of Project SQUID, sponsored by the Office of Naval Research.

[1] H. C. H. Townend, Aero. Research Council (Great Britain), Rept. and Mem. 1803 (1937); H. J. Bomelburg, Univ. of Maryland, Tech. Note No. BN-68 (February, 1956).

B2. Hugoniot Equation of State from Oblique Shock Measurement. SAMUEL KATZ, D. R. CURRAN, AND D. G. DORAN, *Stanford Research Institute.*—A method using an explosive-produced oblique shock in a wedge-shaped specimen has been developed for measuring the Hugoniot equation of state of solids. Simultaneous measurement of shock and free-surface velocities along the wedge face permits calculation of pressure and density over a pressure range exceeding 2:1 on a single shot. In aluminum a range of 40–180 kb was studied. The results are in good agreement with the normal shock method of Walsh *et al.* The data for low-carbon steel may be interpreted in terms of a two-shock system. The faster shock has a nearly constant velcoity of 5.13 mm/μsec, a maximum amplitude near 135 kb, and is observed to decay to 100 kb in about 50 mm. The existence of the slower shock is inferred from the data. The interpretation of this two-shock system by Minshall and Bancroft, in terms of a polymorphic transition in iron, is tested by an experiment with a wedge of antimony, for which Bridgman reports a static transition at 84 kb. The corresponding dynamic transition occurs near 95 kb.

B3. Permanent Wave-Like Surface Deformations Produced on a Metallic Slab by Oblique Impact of a Thin Sheet.* GEORGE R. ABRAHAMSON, *Stanford Research Institute* (introduced by G. E. Duvall).—A flat-nosed steel bullet which is shot at an angle into a thin sheet of metal may acquire permanent periodic deformation on its front surface.[1] Generally similar, but not identical surface deformations are produced when a thin sheet of metal is driven at an angle into a thick metal slab by an explosive charge. In high velocity impact problems such as these, many of the effects observed can be satisfactorily explained by considering the metals as liquids. From experiments at relatively low velocities using materials such as water and silicone putty, which are liquids under appropriate conditions, a plausible mechanism of wave formation was envisaged. It is believed that the permanent periodic surface deformations produced with metals are due to a similar mechanism.

* Supported in part by the Office of the Chief of Ordnance, U. S. Army.

[1] Allen, Mapes, and Wilson, J. Appl. Phys. **25**, 675 (1954).

B4. Free Molecule Probe Studies of High Speed Leading Edge Flows in a Rarefied Gas.* J. A. LAURMANN, *University of California, Berkeley* (introduced by S. A. Schaaf).—A study of the structure of the two-dimensional flow near the leading edges of a flat plate and a wedge at zero incidence was made with the aid of a free molecule probe. Experiments were conducted in the low pressure wind tunnel of the University of California, in which the density is low enough to enable a fine 0.00025-in. diam "free molecule" wire probe to be used without disturbing the flow. By measuring both the temperature and the heat transfer coefficient of the wire, it was possible to obtain a qualitative picture of the boundary layer and shock wave structure near the leading edges of the models. The Mach number range was from 2 to 6, with stagnation temperature equal to the ambient value of approximately 20°C, and Reynolds numbers varied from 150 to 2000/in., the region investigated extending from the leading edge to approximately 1 in. downstream.

* Work performed under the sponsorship of the Wright Air Force Development Center.

B5. Electron-Optical Visualization of Gas Flow at Pressures below 10^{-4} mm Hg.* L. MARTON, D. C. SCHUBERT, AND S. R. MIELCZAREK, *National Bureau of Standards.*—Dark-field schlieren technique, using electrons instead of light, has been developed for the study of gas flow problems at pressures below 10^{-4} mm Hg. Electrons scattered through small angles in collisions with individual gas molecules are focused to form an image of the region under study, while the main beam of unscattered electrons is collected on a small metal stop. The image thus formed is an orthographic projection of the distribution of gas density and is thus ideally suited to the study of two-dimensional flow. The sensitivity of the method may be enhanced by several orders of magnitude by minimizing the residual gas pressure in the apparatus. At present, collimated beams of cadimum vapor at a density equivalent to 10^{-4} mm pressure are easily photographed with a 3-sec exposure. An instrument is being built which will

combine the schlieren technique with mechanical chopping of the atomic beam and synchronous pulsing of the electron beam. A two-dimensional representation of the distribution of molecules in velocity space after reflection from a solid surface will be produced, thus permitting one to calculate the coefficients of temperature accommodation and viscous slip.

* This work is supported by the Office of Naval Research.

B6. Flash X-Ray Determination of Density Ratio in Gaseous Detonations.* HERBERT T. KNIGHT AND RUSSELL E. DUFF, *Los Alamos Scientific Laboratory.*—In the hope of clarifying the thermodynamic-hydrodynamic state in the wake of gaseous detonation waves, Chapman-Jouguet density ratios have been measured in several gas mixtures by means of an x-ray absorption technique. In addition to results for acetylene-oxygen mixtures previously reported,[1] data are now available for stoichiometric hydrogen-oxygen mixtures, and both stoichiometric and fuel-lean cyanogen-oxygen mixtures. As was the case with acetylene-oxygen, the observed density ratios are in the neighborhood of 1.66. However, an appreciable diameter effect has been observed. Preliminary work on its magnitude indicates that our measurements are 2½% low. Taking this into account, the measured density ratios correspond most nearly to those calculated using a frozen composition sound speed.[2] Higher densities have been observed when initiation was inadequate, or the wave traveled a distance insufficient for essentially steady-state conditions to be established. In such cases velocity measurements showed no wave abnormality, demonstrating the sensitivity of density as a measure of conditions behind a detonation wave.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

[1] R. E. Duff and H. T. Knight, J. Chem. Phys. **25**, 1301 (1956).
[2] J. G. Kirkwood and W. W. Wood, J. Chem. Phys. **22**, 1915 (1954).

B7. Vibration and Dissociation Relaxation Rates of Molecular Oxygen in Argon Oxygen Mixtures.* MORTON CAMAC AND CHARLES PETTY, *AVCO Research Laboratory.*—The relaxation times for vibration excitation and dissociation of O_2 were obtained in shock wave heated oxygen-argon mixtures in the temperature range from 1400°K to 5500°K. The O_2 ground vibrational state concentration was observed by its absorption of 1471 A ultraviolet light (in the Schumann-Runge absorption region). Radiation from a xenon resonance lamp (1471 A) traversed the shock tube normal to its axis and its attenuation by the gas was measured. Argon, N_2, N, and O are transparent to this wavelength and, thus, O_2 can be detected even in small dilution. At room temperatures a partial pressure of 0.1 mm O_2 gives a 15% absorption of this radiation. Data were obtained for a range of mixtures from ¼% to 20% O_2 in argon. A preliminary analysis of the data shows that the vibrational excitation of O_2 by argon is about 0.1 as effective as by oxygen. An analysis of the dissociation relaxation will also be presented.

* This work is sponsored by the Ballistic Missile Division, Air Research and Development Command, U. S. Air Force.

B8. Shock Tube-Interferometer Measurements of the Rate of Dissociation of Oxygen.* D. L. MATTHEWS, *Princeton University* (introduced by W. Bleakney).—Shock waves in oxygen at $M \cong 10$ and initial pressure about 10 mm have been observed in a new shock tube. Marked relaxation is visible, extending a few mm behind the shock. In examining this reaction zone, we are using an equation of the form $-d[O_2]/dt \propto PZ(D/RT)^{s/2} \exp(-D/RT)$, where Z is the total number of collisions per unit volume per second, D is the dissociation energy, P is the fraction of sufficiently energetic collisions which actually produce dissociation, and S depends on how much energy stored in internal modes of colliding molecules is available to produce dissociation. At the time of writing only the final equilibrium state has been checked. The density there agrees, within experimental error, with the value calculated assuming that dissociation has negligible effect on the refractive index, and that vibrational states reach equilibrium much faster than dissociation does. Initial and final temperatures, corresponding to zero and ~10% dissociation, are computed to be ~4800 and 3200°K, with densities respectively ~7 and 10 times that ahead of the shock.

* Work supported by the Office of Naval Research.

B9. Measurements of the Hugoniot and Adiabat for Explosive Reaction Products. W. E. DEAL, *Los Alamos Scientific Laboratory.*—When a detonation wave impinges upon an inert material in contact with an explosive, a shock wave is transmitted into the inert and a shock or rarefaction reflected into the reacted explosive gases. Determining the hydrodynamic state behind the shock in the inert, the continuity of pressure and particle velocity across the interface enables one to establish the state in the reaction products. The presence of the Taylor wave behind the detonation wave gives rise to a rarefaction following the shock in the inert; hence the determination of the inert state must be made near the interface before decay of the shock occurs. Measurements have been made for Composition *B* in contact with uranium, brass, 24ST aluminum, magnesium, water, hexane, pentane, 0.50 g/cc and 0.14 g/cc polyurethane foam plastics, argon, and air. Only one hydrodynamic variable of the inert was measured; the others were established using Hugoniots determined independently. Free-surface velocities were measured for the metals. Shock velocities for the liquids were determined using liquid wedges and mibroballoon flashers. Foam plastic shock velocities were established from transit times through thin disks. Gas shock velocities were measured directly using the gas shock luminosity.

MONDAY EVENING AT 8:00

(W. M. ELSASSER presiding)

C1. Re-Entry into the Atmosphere. ARTHUR KANTROWITZ, *AVCO Research Laboratory.* (30 min.)
C2. Energy Principle for Hydromagnetic Stability Problems. E. A. FRIEDMAN, *Princeton University.* (30 min.)

TUESDAY MORNING AT 9:30

(L. S. G. KOVASZNAY presiding)

D1. Broszko's Theory of Turbulence—A Preliminary Survey. WILLIAM SQUIRE, *Bell Aircraft Corporation.*—This is a preliminary report on the application of Broszko's theory[1] to simple problems such as pipe, Couette, and boundary layer flow. It is shown why at a distance from walls turbulent flow can be approximated by laminar flow with slip at the

wall. Using this as first approximation give a logarithmic term in the next approximation but the sequence obviously diverges. Another approximation for fully developed turbulence gives a square root velocity distribution. The agreement with experiment can be seen by comparing $u^*=11+\frac{1}{2}\sqrt{y^*}$ with the usual expression $u^*=5.5+2.5\ln y^*$.

[1] M. Broszko, Ann. acad. sci. tech. Varsovie **7**, 75–98 (1939–1945).

D2. Turbulent Convection of a Scalar Field at High Reynolds Numbers.* ROBERT H. KRAICHNAN, *New York University.*—An analytical theory of turbulence[1] is extended to the turbulent convection of a passive scalar field. At sufficiently high Reynolds numbers, the theory for the stationary, isotropic case predicts an "inertial" range in which the autocorrelation functions at wave number k are identical for velocity and scalar fields and are given by $J_1(2v_0k\tau)/(v_0k\tau)$, where v_0 is the rms velocity in any direction. The inertial-range scalar field one-dimensional spectrum function is $c'\alpha(v_0/\epsilon)^{\frac{1}{2}}k^{-\frac{1}{2}}$, where α is the rate of supply (at subinertial wave numbers) of mean-square scalar field fluctuation, ϵ is the velocity field energy-dissipation rate/unit mass, and c' is a universal number fixed by the theory. This result, like the previously obtained velocity spectrum,[1] contradicts the Kolmogorov-Obukhov dimensional hypotheses. Elementary physical considerations are presented which indicate failure of the Kolmogorov arguments and support the present theory. Extension of the present theory to anisotropic turbulence predicts anisotropy of the modal autocorrelation functions which persists above the inertial range.

* Supported by the Geophysics Research Directorate, Air Force Cambridge Research Center.

[1] R. H. Kraichnan, Report MH-7, Division of Electromagnetic Research, Institute of Mathematical Sciences, New York University (April, 1957); Bull. Am. Phys. Soc. Ser. II, 2, 307 (1957).

D3. Large Eddies of Turbulent Motion. H. L. GRANT,* *Cavendish Laboratory, England* (introduced by A. M. Patterson).—Nine components of the double velocity correlation tensor and some correlations with separations in directions other than the axial ones, have been measured in the wake of a circular cylinder and in a "flat plate" boundary layer. In the wake, the correlations at large values of the separation are explained in terms of two types of large scale motion. One of these is a pair of vortices, side by side, and rotating in opposite directions with axes aligned approximately normal to the plane of the wake. The other typical motion is a series of jets in which turbulent fluid is projected outward from the core of the wake. It is suggested that the jets are the result of an instability of the turbulent shear stress and a qualitative explanation of the constancy of the shear coefficient in the wake is given in terms of this instability. The vortex pair eddies were not found in the boundary layer but there is evidence of jets much like those in the wake. Correlations measured in grid turbulence have been found to be highly anisotropic and consistent with the presence of vortex pair eddies.

* Present address: Pacific Naval Laboratory, H.M.C. Dockyard, Esquimalt, B.C., Canada.

D4. Approach to Particle Dispersion by Turbulent Fluid.* J. L. LUMLEY, *The Johns Hopkins University* (introduced by S. Corrsin).—The motion of a spherical particle in turbulent fluid is governed by $X_i(a_k,t)=a_i+\int_0^t g(t-\tau)u_i(X_j(a_k,\tau),\tau)d\tau$ (where $g(t)=1-e^{-\alpha t}$), when time and length scales associated with the particle are small compared with the flow field.[1] Particle motion statistics are expressed in terms of Eulerian statistics by a lemma which assures, for an incompressible flow, the equality of the probability densities of the events (1) "The right- and left-hand sides of the above equation differ by less than ϵ on the interval $[O,T]$ when $X_i(al_j,t)$ is replaced by an arbitrary function $Z_i(t)$ satisfying the same initial conditions" and (2) "$X_i(a_k,t)$ differs from $Z_i(t)$ by less than ϵ on the interval $[O,T]$." The position density is then formulated as a multiple integral similar to the Feynman integrals.[2] Knowledge of the Eulerian characteristic functional is necessary for the position density at a single time. Direct integration to obtain the density has not been possible even if the Eulerian characteristic functional is taken as Gaussian; however, an expansion about the case of a spatially constant flow field can be developed.

* This research was supported by the Mechanics Branch, U. S. Office of Naval Research.

[1] J. L. Lumley, Report to the Mechanics Branch, U. S. Office of Naval Research, under contract Nonr 248(38) May, 1957.

[2] R. P. Feynman, Revs. Modern Phys. **20**, 367 (1948).

D5. Measurement of Total Head Fluctuations with a Pressure Transducer. B. A. HUGHES, *Pacific Naval Laboratory, Canada* (introduced by W. N. English).—Small specially designed pressure transducers have been used in a water tunnel to study the total head fluctuations behind objects whose wakes have been extensively examined in air. The decay in intensity and the change in the fluctuation spectra have been measured as a function of a downstream distance directly behind single circular cylinders and parallel bar grids. The results obtained so far agree quite closely with measurements made by Townsend[1] using hot-wire techniques in a wind tunnel.

[1] A. A. Townsend, Australian J. Sci. Research **A2**, 452 (1949).

D6. Hot-Wire Measurements of Turbulence Spectrum Decay in a Tidal Channel. A. M. PATTERSON, *Pacific Naval Laboratory, Canada.*—Three stations were occupied in the channel north and three in the channel south of Seymour Narrows to determine the changes that occur in the spectrum of the turbulent jet generated in the Narrows. The turbulence in this region is quite marked and the visual indications of its intensity could easily be seen five miles downstream of the Narrows. The channel to the south is about three times as wide but not much deeper than the Narrows, and the decay of the spectrum of the turbulent jet could be measured but was somewhat masked by the turbulence being generated on the sides and bottom of the channel. The decay of the turbulence spectrum could more easily be observed in the deeper north channel. Some typical records will be presented. Just north of the Narrows a check was made of the vertical variation of the turbulence and it was found that both the intensity and the spectrum changed markedly with depth. Two different types of hot-wire equipment were used in the operation and a comparison is made of the characteristics of constant-current and constant-temperature hot-wires.

D7. Diffusion in a Moving Medium. KURT FORSTER, *University of California, Los Angeles.*—The problem of diffusion, for instance of heat, in a moving medium with moving boundaries involves the combined influence of conduction and thermal transport. Let the fluid be incompressible and inviscid and the motion be given; conditions of vanishing temperature or vanishing heat flux are imposed on the boundary $r_0(t)$. Instead of approximating the differential equation, the *motion of fluid and boundary is approximated* which can be done in such a way that (a) the boundary conditions are fulfilled for every approximating motion (b) the exact solution for the problem for the approximating motion is made up of solutions of *pure conduction* problems assumed known, (c) the approximating motion tends to the given motion in the limit. The result is that the original problem can be calculated to any desired degree of accuracy by repeated integrals of the form

$$T(\bar{r},t+\Delta t)=\int_{\bar{r}_0(t)}^{\infty} T(\bar{r}',t)G[(\bar{r}-\Delta\bar{r}),\bar{r}',\Delta t]dx'dy'dz',$$

where $G(\mathbf{r},\mathbf{r}',t)$ is the Green's function for a pure conduction problem.

D8. Unsteady Couette Flow.* LESLIE A. HROMAS, *Purdue University* (introduced by G. A. Hawkins).—The basic equations for unsteady, compressible, plane Couette flow indicate that transverse velocities can be generated by the unsteady longitudinal shearing motion of the moving wall. Linearizing the equations of motion shows that, due to the shear flow, this effect exists independent of viscous dissipation, and thus can be investigated on a low speed basis. Analytically, an order of magnitude analysis was employed making use of a suitably defined boundary layer displacement thickness, based on the incompressible solution, and considering its rate of change as indicative of the transverse velocity. An experimental demonstration of the existence of the transverse velocities was conducted using concentric rotating cylinders to simulate the flow. Velocity profile measurements checked closely with the known unsteady incompressible solution, indicating any transverse velocity was too small to be measured directly. Its magnified effect on the temperature variable was then measured by placing a temperature gradient across the annulus. The periodic temperature fluctuations noted were converted to an equivalent transverse velocity. Experimental values obtained agreed qualitatively with the "theory." Finally, the role of free convection and centrifugal force in the experimental apparatus was considered.

* Supported by the Office of Ordnance Research.

D9. Time Constants and Frequency Response of Coated Hot Wires Used as Turbulence-Sensing Elements. AVIS BORDEN, *David Taylor Model Basin.*—A theoretical analysis has been made of the unsteady heat flow through a solid cylindrical wire containing heat sources and a coating in the form of a cylindrical shell. The probelm was linearized and the solutions for the constant current and constant temperature coated wires were obtained for a step-like change in convective cooling. An equivalent time constant was obtained for each case. The frequency response of each wire to sinusoidal changes in convective cooling was obtained by applying Duhanel's theorem.

D10. On the Decay of Homogeneous Turbulence before the Final Period. ROBERT G. DEISSLER, *Lewis Flight Propulsion Laboratory* (introduced by James W. Blue).—A three-point correlation equation constructed from the equations of momentum and continuity is used to obtain a relation for the triple correlations applicable, to the decay of turbulence, at times before the final period. In this case, the equation is made determinate by neglecting the quadruple correlations. Higher order approximations, valid at still earlier times, could be obtained by considering four- or five-point correlation equations. In each ease, the set of equations is made determinate by neglecting the highest order correlation. Only two- and three-point correlation equations are considered here. The correlation equations are converted to spectral form by taking their Fourier transforms. Expressions are obtained for the energy transfer function and for the energy spectrum function. By integrating the energy spectrum over all wave numbers the following energy decay law is obtained: $\langle u^2\rangle = A(t-t_0)^{-1} + B(t-t_0)^{-7}$ where $\langle u^2\rangle$ is the mean square of the velocity fluctuation, t is the time, and A, B, and t_0 are constants determined by the initial conditions. Comparison of the decay law with experimental data indicates good agreement for times considerably before as well as during the final period.

TUESDAY AFTERNOON AT 2:30

(OTTO LAPORTE presiding)

E1. Hydromagnetic Channel Flow. HAROLD GRAD, *New York University.*—In the flow of an ionized gas through a channel (e.g., in a high-temperature wind tunnel), heat losses and recombination at the wall can be reduced by "insulating" the walls from the gas by a magnetic field. If the ionized gas approximates a perfect conductor, the magnetic field can be used as a replacement for the wall. We consider flow of a perfect conductor through a channel of slowly varying circular cross section guided by a surrounding axial field (i.e., along the direction of flow) which is itself contained within a concentric, perfectly conducting, fixed shell. Given the longitudinal variation of the cross section of the external conductor, one can compute the variation of all flow quantities, including the area of the fluid channel. Stability considerations show that no transition from subsonic to supersonic (as in a Laval nozzle) can occur with such magnetic walls replacing the physical walls.

E2. Application of Magnetohydrodynamics to Flight.* T. BROGAN, A. KANTROWITZ, R. PATRICK, H. PETSCHEK, AND R. ROSA, *Avco Research Laboratory.*—The interest in magnetohydrodynamics (MHD) has been spurred primarily by astrophysical problems and by problems associated with the fusion reactor. More recently it has been suggested that MHD may be applicable to high-speed flight problems. The fundamental advantage offered by MHD is that it becomes possible to exert forces on a fluid without the use of solid surfaces and hence, for example, avoid the high heat transfer encountered in hypersonic flight. The primary factor limiting the range of applicability of MHD is the magnitude of the electrical conductivity that it is possible to induce in the air stream. If one assumes conductivities corresponding to those produced by bow shock waves on an object, one can outline flight regions in which MHD devices should be superior to conventional aerodynamic shapes. These regions are of rapidly increasing importance since they include, among other things, the critical parts of satellite re-entry trajectories. The results of some preliminary calculations and experiments on MHD flow properties is also presented.

* This research was supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command.

E3. Plasma Heating of Hypersonic Air Flow.* RAYMOND L. CHUAN, *University of Southern California.*—For the production of condensation-free hypersonic flow in a wind tunnel it is proposed to add energy to the electrons in the air downstream of the throat by high-frequency electrodeless discharge, and allow electron energy to go into random kinetic energy of the molecules in the decay process. Previous work in this respect[1,2] has dealt only with the discharge process, measuring the energy that can be added to the plasma by various types of discharges. The present work examines the decay processes in an attempt to channel as much of the electron energy as possible into raising the temperature of the gas, by preventing losses by ambipolar diffusion and radiation, the former representing the predominant loss mechanism. Inhibition of ambipolar diffusion by means of an axial constant magnetic

field is examined, as well as the attendant possibility of having such an inhibiting effect nullified by drain diffusion resulting from hydromagnetic instability. An experimental investigation is being initiated.

* This work is sponsored by the Air Force Office of Scientific Research.
[1] D. E. Bloxom, "Production of high temperature, moderate pressure gasses by electric spark discharge," Arnold Engineering Development Center, Tech. Note 56-17 (November, 1956).
[2] H. C. Early and D. B. Miller, "Heating in supersonic air stream by corona discharge," University of Michigan TR 2147-16-T (April, 1957).

E4. Dynamic Stabilization of Hydrodynamic and Hydromagnetic Instabilities.* HOWARD D. GREYBER, *University of California Radiation Laboratory.*†—The gravitational instability of two superposed incompressible fluids of different densities is investigated with an oscillating velocity imposed, (a) vertically and (b) horizontally. One finds that the system is partially stabilized by the imposed oscillation. We also consider the hydromagnetic analog of case (a) where a perfectly conducting fluid is supported against gravity by a horizontal magnetic field. In case (a) the analysis leads to Mathieu's differential equation and in case (b) to two coupled linear second order differential equations with periodic coefficients. The stability properties of the differential equations in case (b) were studied on the Univac with the help of Floquet's theorem.

* Work performed under the auspices of the U. S. Atomic Energy Commission.
† Now with General Electric Research Laboratory, Schenectady, New York.

E5. Hydromagnetic Instability of Cosmical Bodies. K. P. CHOPRA, *University of Maryland* (introduced by J. M. Burgers).—The properties of the current-driven hydrostatic magnetic fields in a fluid nonrotating (a) sphere (b) infinite cylinder, and their effect on the instability of these bodies forms the subject matter of this paper. It is shown that a force-free magnetic field must be a suitable combination of poloidal and toroidal components such that the magnetic energy is equally divided among them. On the other hand, a pressure-bound magnetic field may either be purely poloidal or purely toroidal, or a suitable combination of both. The equilibrium configuration of an arbitrarily deformed sphere is an oblate spheroid for a pure poloidal field, and a prolate spheroid for a pure toroidal field. These configurations are found to be stable. For radial adiabatic pulsations of the sphere, the pulsational frequency is found to decrease with a poloidal and increase with a toroidal field. On the other hand, the cylinder is stable in a poloidal field while the toroidal field adds to its instability. The problems discussed, though highly idealized, are of interest in the understanding of the structure and stability of cosmical bodies like spiral nebulae and magnetic stars.

E6. Measurements of Flow Properties in a Dissociated Gas.* C. E. TREANOR, T. C. GOLIAN, AND A. HERTZBERG, *Cornell Aeronautical Laboratory.*—Direct measurements of the speed of sound have been performed in dissociated gases. The sound wave is produced by an abrupt expansion in the shock tube and the velocity of the expanding cylindrical wave is determined from a schlieren photograph taken a known time later. A comparison of these results with calculated values of the speed of sound indicates that waves produced in this manner propagate as though vibration and dissociation do not participate.

* This research was partially supported by the U. S. Air Force through the Air Force Office of Scientific Research of the Air Research and Development Command and through the Research Division of the Bell Aircraft Corporation.

E7. Hypersonic Flow in Helium at Mach Numbers above 20.* ROBERT H. JOHNSON, *General Electric Research Laboratory.*—A helium tunnel designed for performance in the Mach number range between 20 and 30 has been in operation at the General Electric Research Laboratory for over a year. The tunnel is of the blowdown type utilizing a pressurized helium supply and exhausting into a battery of vacuum pumps. Experiments thus far have been concerned primarily with the flow over blunt bodies. Several series of experiments will be described. In particular, a set of successively more blunted hemispheres was studied, as were a series of successively more blunted cone-hemisphere bodies. The shock wave properties in these studies show the strong influence of the body sonic point location. A correlation was made of the measured centerline shock wave detachment distance with the theories of Li and Geiger, and of Heybey for the hemisphere, and Probstein for the flat bodies.

* Work supported by the U. S. Air Force, Western Development Division.

E8. Contribution to the Theory of Meteorite Ablation. GEORGE W. SUTTON, AND ROBERT F. HUGHES, *General Electric Company* (introduced by J. Farber).—The ablation problem has usually been treated by equating the rate of heat transfer to the product at the rate of vaporization and the latent heat for vaporization. For such calculations, the ratio of the rate of energy transfer to the meteorite surface to the total energy flux available has been assumed constant. Expressions for the heating rate are derived in which the heat transfer ratio varies with altitude and velocity. The heating rate is then used as the boundary condition for the heat conduction into the meteorite. With the assumption that as the meteorite surface is melted, the melt is immediately removed, the temperature profiles in the meteorite are then calculated. The results indicate that the region of temperature increase is very narrow, which is consistent with observations of known meteorites. The generality of this conclusion is not affected by the assumption. Finally, the above assumption is relaxed, and the Navier-Stokes equations are applied to determine the detailed motion and temperature profiles of the melt. Criteria are presented concerning the conditions for which the presence of the melt must be included in the analysis, and the conditions for which vaporization of the liquid may be expected.

E9. Pitting in Ablating Bodies Subject to Hypersonic Airflow. DAVID T. WILLIAMS, *University of Florida.*—A careful photographic study of the flow markings on certain meteorite surfaces was made to determine whether pitting of the surface is a phenomenon of aerodynamic origin. The data are reviewed and exhibited in the form of slides, which have been concluded to demonstrate that pitting of meteorites is caused by stationary vortices in the boundary layer of the air flow. Pitting of an essentially similar type is shown to exist under widely different circumstances, as predicted on the basis of the meteorite study.

E10. Radiative Properties of High Temperature Air.* W. H. WURSTER AND C. E. TREANOR, *Cornell Aeronautical Laboratory, Inc.*—The optical properties of high-temperature air have been studied, using a shock tube to heat the air to temperatures up to 6000°K. Emission from the gamma bands of NO and the Schumann-Runge system of O_2 has been observed. Strong absorption by molecular oxygen has been correlated with transitions from excited vibrational levels of the ground state. Rotational transitions as high as $K=51$ are clearly identified in the (2,9) vibrational transition fo the Schumann-Runge system. The line widths correspond to an optical collision diameter of about 10 A. Since the times involved in the experiment are sufficiently long so that thermal equilibrium should be established, it should be possible to obtain absolute transition probabilities from this type of experiment. Both the experimental apparatus and the date obtained will be discussed.

* This work was supported by the Air Force Special Weapons Research Center, Kirtland Air Force Base, New Mexico.

E11. Optical Tracking of Earth Satellites. JOHN S. RINEHART, *Smithsonian Astrophysical Observatory.*—Responsibility for optical (both visual and photographic) tracking of earth satellites is assigned to the Smithsonian Astrophysical Observatory. A well-integrated program has been formulated and is now being implemented. The program provides for (1) establishment, when necessary to supplement radio tracking, of preliminary orbital parameters through amateur teams of observors (MOONWATCH); (2) precise photographic observations from twelve widely scattered stations using at each station a specially designed, complex tracking camera which incorporates in its design a 31-inch Schmidt-type mirror; and (3) a data processing and computation center. Russian launchings of earth satellites have considerably accelerated and reshaped the program. The bulk of the observational data has come from MOONWATCH and other volunteer observors. The data are rough, position usually good to one degree and time to one second, but sufficiently accurate to fix closely the orbital parameters of the several sputniks. Graphical methods and hand computational procedures proved surprisingly valuable during initial stages. Refined computations were made on digital computers. A rough determination of air density at 220-km altitude, which is corroborated by the Naval Research Laboratory, gives a value several times greater than that given in the ARDC model atmosphere.

TUESDAY EVENING AT 7:00

(F. N. FRENKIEL presiding)

Tenth Anniversary Banquet of the Division of Fluid Dynamics at Hotel Bethlehem

After-dinner speaker: JOSEPH KAPLAN, *I.G.Y. and the Physics of Fluids.*

WEDNESDAY MORNING AT 9:00

(J. H. MCMILLEN presiding)

F1. Experiments on Chemical Kinetics in Supersonic Flow. PETER WEGENER, *Jet Propulsion Laboratory.* (30 min.)

F2. Calculation of Reaction Zone Structure behind Shock Waves.* RUSSELL E. DUFF, *Los Alamos Scientific Laboratory.*—An arbitrary system of kinetic equations subject to the hydrodynamic restraints appropriate for the steady flow behind a shock is integrated on an IBM-704. The profile for a hydrogen-oxygen detonation is presented along with several profiles for the shock dissociation of O_2 based on different rate constants and reaction mechanisms. Conclusions apparent from the O_2 calculations are (1) a mechanism involving the formation of O_3 does not make a significant contribution to the dissociation rate; (2) the concept of "relaxation times" must be used with caution. A relaxation time as usually defined is only appropriate for the description of the approach to equilibrium. It can be shown that then

$$\tau^{-1}=C\left\{k_D+4C_Ak_R-C_A{}^2\frac{dv}{d\lambda}k_R+\left[C_A{}^2\frac{dk_R}{d\ln T}-C_{A_2}\frac{dk_D}{d\ln T}\right]\times\left[\frac{\rho/\rho_0+p_0/p-2}{\rho/\rho_0-1}\frac{dv}{d\lambda}-\frac{1}{C}\right]\right\},$$

where C is the concentration and λ is a progress variable. The variation of rate constants with temperature and the associated shift of the equilibrium dominates this expression.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

F3. Shock-Induced Phase Transitions in the Alkali Halides and in Phosphorus. RUSSELL H. CHRISTIAN AND BERNI J. ALDER, *University of California Radiation Laboratory.*—The transition of the rubidium and potassium halides from f.c.c. to the b.c.c. crystal structure has been observed in shock waves by equation of state measurements. The volume *vs* pressure data are in excellent agreement with the data of Bridgman, but does not extend down to the transition point; thus the pressure of the transition cannot be compared. The polymorphic transition in red phosphorus to the black crystalline phase has been observed by a measurement of the electrical conductivity during the passage of a shock. The recovery of the black form after the experiment has allowed a positive identification by x-ray diffraction. Yellow phosphorus can also be converted to the black form at a pressure of about 80 000 atmos. Below that pressure the recovered yellow phosphorus is virtually unchanged. These are the only irreversible transitions presently known to occur during a shock. Data from the above experiments imply that the relaxation time for recrystallization is too short to have been observed, i.e., less than $\frac{1}{10}$ μsec.

F4. Transition from Slow Burning to Detonation in Gaseous Explosives. FREDERICK J. MARTIN, *General Electric Laboratory.*—High-speed photographic observations have been made of flame structure, flame velocity, and shock velocity during the transition from slow burning to detonation in acetylene-oxygen mixtures contained in glass pipe at reduced pressures. During intermediate stages the dome-shaped flame travels down the tube at about 800 m/sec and is preceded by a shock wave traveling slightly faster. During the final stages of formation of the detonation wave, the flame changes shape, accelerates, and advances along the walls in an asymmetric manner. The detonation first appears at, or slightly behind, the leading edge of the flame. The final flame acceleration occurs when the Reynolds number of the mass flow between the flame and the preceding shock, based upon the distance between the two, is about 10^4. Under these conditions a transition from a laminar to a turbulent boundary layer flow appears likely. Changes in flame structure which result in the final acceleration and the formation of the detonation wave, appear to result from the formation of a turbulent boundary layer in which the flame propagates faster than in the free-stream region.

F5. Interferometric Observations of Hydrogen-Air and Hydrogen-Oxygen Detonation. DONALD R. WHITE, *General Electric Research Laboratory.*—Interferograms taken during the formative phase of spark-initiated low-pressure hydrogen-air detonations have shown a high subsonic flow ahead of the shock with accompanying precompression. The interaction of the shock wave with the boundary layer associated with this flow is such as to result in higher pressures and temperatures

at the wall behind the shock than in midstream. Pictures of low pressure $2H_2+O_2$ detonations traveling at constant velocity in the 3½-in. tube show irregular variations in density behind a nonplanar front. These density variations are markedly different from those smooth profiles observed in a one-dimensional dissociation or ionization relaxation process. The aplanarity of the wave decreases but does not disappear at the lower pressures as better mixing of the reactants is achieved. These observations suggest that the coupling between the strength of the shock wave and the reaction rate behind the shock introduces a basic instability in the detonation wave front. Techniques of interferometry are shown to be readily applicable to the study of gaseous detonation.

F6. Transition from Laminar to Turbulent Flow in the Shock Tube Boundary Layer.* ALBERT J. CHABAI AND RAYMOND J. EMRICH, *Lehigh University*.—Hollyer, Bershader, Bromberg, Rott and Hartunian, and Mirels have developed a laminar shock tube boundary layer theory which predicts a step-function variation of the wall temperature with shock passage. Wall temperature is recorded by evaporated thin film resistance thermometers. Following the predicted step function, a further temperature rise is observed which is nearly proportional to the square root of time. This departure from constant temperature is interpreted as the transition from laminar to turbulent flow in the boundary layer. The transition time τ (the duration of the step-function part of the temperature record) has been measured for various initial channel pressures and shock strengths in nitrogen. Data include shock strengths $1.2<P_{21}<5.5$ and initial channel pressures 10 mm Hg. $<P_1<7000$ mm Hg. If these data are correlated in terms of Reynolds numbers involving τ, the kinematic viscosity of the hot gas ν_2, and the gas and shock velocities relative to the tube wall u_2 and V_s, the following numbers are obtained: $\tau u_2^2/\nu_2=4\times10^5$ and $\tau u_2^2 V_s/(V_s-u_2)\nu_2=6\times10^5$.

* Supported by U. S. Office of Naval Research.

F7. Turbulent Boundary Layer Fluctuations at Supersonic Velocities. ALAN L. KISTLER,* *Ballistic Research Laboratories* (introduced by P. Wegener).—The fluctuations in a turbulent boundary layer without pressure gradient have been measured with a hot wire anemometer for Mach numbers up to $M=4.6$. The distribution of the static temperature fluctuation levels through the boundary layer is similar at the various Mach numbers, and the levels are proportional to the mean static temperature difference across the boundary layer. A slight decrease of the velocity fluctuation levels is observed as the Mach number is increased. There is a high negative correlation between the velocity and temperature fluctuations at all Mach numbers.

* Now at the Jet Propulsion Laboratory, Pasadena, California.

F8. Resonance Tube in Supersonic Flow. THOMAS VREBALOVICH, *Jet Propulsion Laboratory, California Institute of Technology* (introduced by P. Wegener).—The air column in some configurations of a cylindrical total head tube, with its downstream end closed, resonates at a very large amplitude when it is placed in a high-velocity air stream; and the base of the tube gets hotter than the free-stream stagnation temperature. Experiments were conducted with two models: one model, which had a movable piston at its base, was instrumented with pressure transducers, thermocouples, and static pressure taps; the other was an optical model. From the measurements of pressure and density distribution made on these models, it was found that the resonance tube gets hot because the air that remains within the tube at the end of each cycle has its entropy increased on succeeding cycles by shock waves which are the main dissipative process in the tube.

F9. Binary-Mixture Boundary Layer on a Very Slender Body of Revolution.* HARVEY WALLSKOG, *Applied Physics Laboratory, The Johns Hopkins University* (introduced by J. G. Parker).—The laminar boundary layer equations are presented for compressible fluid flow of a nonreacting binary mixture over a body of revolution for the case when the boundary layer thickness is of the same order of magnitude as the radius of the body. It is shown that a suitable transformation exists which allows the slender axially symmetric case with mass transfer to be transformed into a set of equations that are in exactly the same form as the two-dimensional equations. The relationship of the "two-dimensional" friction coefficient to that of a very slender body of revolution is shown. It is noted that numerical solutions of the two dimensional form equations would provide, through the transformation equations, results that are valid for all axial locations on a slender body since no approximations were made regarding the relative thickness of the boundary layer. Briefly reviewed are the works of several authors wherein solutions were obtained in the form of a series expansion valid for various limited axial regions on slender cylinders.

* Based on part of a thesis presented to the Graduate School of the University of Maryland, 1957.

F10. Diffusion Boundary Layer with Surface Combustion. S. M. SCALA, *General Electric Company* (introduced by J. Farber).—The boundary layer equations are derived for the flow of a three component compressible chemically reacting gas at the stagnation point of a blunt body. Two theoretical models are considered for the combustion of a carbon sphere in a high-speed, high-temperature air stream, assuming that homogeneous reactions are frozen and that heterogeneous reactions are diffusion controlled. In the first model, it is assumed that nitrogen is an inert diluent, and hence the only combustion product is CO. In the second, reactions between carbon and nitrogen are allowed and hence the combustion products are CO and CN. In either model, the gas is treated as a three-component mixture requiring simultaneous solution of a ninth-order system of four nonlinear differential equations with split boundary conditions. It is further assumed that the Prandtl and Schmidt numbers are constant, however, the product of density and viscosity is allowed to vary. Analog computer solutions are presented in the form of dimensionless parameters which enable rapid determination of combustion and heat transfer rates for a carbon sphere in a high-temperature airstream.

F11. Investigation of a Shock-Induced Transition in Bismuth.* RUSSELL E. DUFF AND F. STANLEY MINSHALL, *Los Alamos Scientific Laboratory*.—The structure of the shock-wave system to be expected in a material which can undergo a polymorphic transition is discussed. It is shown that the slope of the coexistence line in the p-T plane for the transition can be determined from shock-wave measurements at a given initial temperature. Shock waves produced by high explosives were used to investigate the equation of state of bismuth. An electrical contact technique was used to measure shock and free surface velocities. The transition near 25 kb reported by Bridgman was observed but the transition pressure was about 3.5 kb higher than in static experiments. Other results indicated that recrystallization is a faster process than melting under shock conditions. Evidence suggests that the relaxation time for recrystallization in bismuth at 42°C and 27 kb is less than 1 μsec.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

WEDNESDAY AFTERNOON AT 2:30

(R. E. DUFF presiding)

G1. Mach Reflection of Shock Waves. JOSEPH STERNBERG, *Ballistic Research Laboratories.* (30 min.)

G2. Cylindrical Shock Waves from Exploding Wires. F. D. BENNETT, *Ballistic Research Laboratories.*—Photographic records of single and double wire explosions are shown and discussed. In the experimental arrangement, a capacitor of 0.3 μf at 28 kv delivers 118 joules to the wire in a circuit whose resonant frequency is about 0.5 mc. With a four-sided, turbine-driven, stainless-steel mirror rotating at 1000 rps, mirrorgrams with a time axis of 2.5 mm/μsec are obtained. Streak pictures of exploding 1- and 5-mil wires of Cu and Pd show a characteristic parabolic rise with time. The recent calculations of S. C. Lin for cylindrical shocks show that shock radius r should increase as the square root of time. Plots of $(2r)^2$ *vs* t indicate good qualitative agreement with this law, but difficulties arise in interpreting the slope of the curve. Consideration of the well-known property of Pd to occlude hydrogen to atomic ratios H/Pd>0.7 (approx 1000 cc hydrogen per cc Pd) leads to the supposition that exploding wires of Pd-H may produce enhanced shock waves. Experimental tests of this hypothesis described.

G3. Interaction of Sound Waves with a Stationary Shock.* W. R. JOHNSON AND OTTO LAPORTE, *University of Michigan.*—In contrast to the treatment of Moore,[1] the interaction of plane waves is treated as a boundary value problem. The boundary conditions are the linearized shock conditions on the distorted shock. A noteworthy feature of the problem is that an incident sound wave causes the emergence of both a sound wave and an entropy wave. The analog of Snell's laws and the Fresnel formula are obtained. Using the latter, the interaction of a spherical wave with a stationary shock is calculated. When the sound source is on the supersonic side, the primary excitation is confined to the interior of the Mach cone, and the distortion of the shock is confined to its intersection with that cone. The emerging sound wave is, at large distances, a sphere that is swept downstream with the flow velocity, while the entropy waves are ellipsoidal and confined to the stream tube bounded by the distorted shock region. It is intended to extend these methods to the case of a moving shock, so as to be able to test the calculations in the shock tube.

* Supported by the Office of Naval Research.
[1] F. K. Moore, NACA TN 2879 (1953).

G4. Theoretical Solutions of Spherical Shock Tube Blasts. HAROLD L. BRODE, *The RAND Corporation.*—Calculations have been carried out on two types of explosion which correspond to recent experimental work at the University of Toronto Institute of Aerophysics.[1] The experiments involved the explosion of glass spheres filled to high pressure and high density with either air or helium. A description of the results of the calculations will be presented. The development of the second shock will be shown, as well as the general history of the pressures, densities, particle velocities, and some temperatures. Computational techniques and details will not be covered since that information is available elsewhere.[2,3]

[1] I. I. Glass and J. G. Hall, J. Appl. Phys. **28**, 424 (1957).
[2] H. L. Brode, J. Appl. Phys. **26**, 766 (1955).
[3] H. L. Brode, "Point Source Explosion in Air," The RAND Corporation, RM-1824-AEC (December 3, 1956).

G5. Equation of State of High-Explosive Gas. W. E. DRUMMOND AND G. E. DUVALL, *Stanford Research Institute.*—The acceleration of thin plates by high explosive charges is analyzed as a done-dimensional unsteady flow problem in hydrodynamics. The detonation wave in the (thick) explosive is transmitted into the plate as a uniform shock wave which upon reaching the free surface of the plate is reflected as a centered simple rarefaction wave, and in the process the free surface of the plate is accelerated to a velocity v. The simple rarefaction wave is in turn reflected from the (explosive) gas-plate interface as a compression wave. Succeeding reflections further accelerate the free surface. In the u,l (or hodograph) plane of the plate the entire flow maps into a region which lies between the map of the free surface and the map of the gas-plate interface. The map of this interface depends on both the known equation of state of the plate and the unknown equation of state of the burned explosive gas. It is shown that the location of the map of the interface in the hodograph plane can be determined by measuring the free surface velocity of the plate, and from this the equation of state of the burned explosive gas can be directly inferred. The analysis is applied to experimental data from Los Alamos.

G6. Luminosity of Strong Shock Boundary Layers.* GEORGE CHARATIS AND THOMAS D. WILKERSON, *University of Michigan.*—Certain features of strong shock flows in the rare gases are made self-luminous by addition of small amounts of organic vapors to the expansion chamber gas of a shock tube. A typical experimental situation is the following: behind a shock wave moving with velocity 2.989 mm/μsec through a 99.5% neon−0.5% CH_4 mixture, the flow velocity is ~2.19 mm/μsec, pressure ~84.9 cm Hg, temperature ~4340°K, and therefore the specific Reynolds number is $\sim 1.15\times 10^4$/cm. A vertical slit photograph shows the main stream C_2 band emission behind the shock to be separated from the wall by a nonluminous laminar boundary layer which grows to a thickness of about 2 mm until transition to turbulence occurs approximately 14 cm behind the shock. The turbulent boundary layer emits the Swan bands of C_2 by virtue of the mixing of cold gas near the wall with hot gas from the main stream. The thickness of the turbulent region appears to grow linearly with distance behind the shock and is 7 mm at the driving interface (42 cm behind the shock).

* This research was supported by the U. S. Air Force Office of Scientific Research, Air Research, and Development Command.

G7. Interferometry in the Strong Shock Regime.* R. A. ALPHER AND DONALD R. WHITE, *General Electric Research Laboratory.*—Interferometric density measurements based on molecular specific refractivity are described for strong shocks. Agreement with shock Hugoniot results for air, N_2, and O_2 are explained in terms of polarizabilities. The ratio of atomic to molecular specific refractivity for O_2 is 1.04. For aerodynamic studies at $M \leq 20$ the dissociation of N_2 is sufficiently small that, although this ratio for N_2 is 1.46, molecular specific refractivity can be used with safety. More generally for gases where the refractivity ratio differs significantly from unity, shock tube interferometry provides a new technique for measuring atomic polarizability. Since the electron refractive index is less than unity and much larger per particle than the index for atoms and ions, one can measure the distribution of electron concentration during ionization relaxation, as well as final equilibrium electron concentrations at densities where other techniques are difficult. This is verified by shock tube experiments. Finally the problem of interpretation of white light and monochromatic interferograms is emphasized in plasmas where the phase and group refractivities for electrons are respectively less than and greater than unity.

* Supported by the Western Development Division, U. S. Air Force.

G8. Performance of Thin Film Gauges in High-Temperature Shock Tube Flows.* ROBERT G. JAHN, *Lehigh University*, AND DAVID WEIMER, *Lockheed Aircraft Corporation*.—Attempts to measure the velocity of reflected strong shock waves in a cylindrical shock tube by platinum film heat flow detectors revealed an anomalous response of these gauges over a certain range of ambient densities and incident shock strengths. In this range, the anticipated thermal response of a gauge to the reflected shock front was replaced by a much larger signal of opposite polarity. This effect was studied primarily with incident shocks of Mach number $M_1=5.5$ in 6 mm of nitrogen reflected normally from a brass end wall, but was found to occur up to $M_1=6.3$ in 3 mm of nitrogen, and down to $M_1=5.0$ in 25 mm. The anomalous response is caused by the establishment of an alternate conducting path between the ends of the film through the partially ionized gas behind the reflected shock. Appropriate modification of the geometry of the films permitted rough measurement of the conductivity of this hot gas, which is in order of magnitude agreement with the degree of ionization expected for this temperature (6500°K). Further modification permitted study of the space and energy distribution of the charge.

* Experiments performed at Lockheed Missile Systems Division.

G9. Initiation to Detonation of High Explosives by Shocks. J. M. MAJOWICZ AND S. J. JACOBS, *U. S. Naval Ordnance Laboratory, Silver Spring, Maryland*.—A reflected light technique was used to measure the velocity of induced shocks and speed-up to detonation velocity in TNT, Pentolite, Composition B, Composition B-3, and 75/25 Cyclotol. The method consisted of placing a light reflecting aluminized Mylar film in contact with the free surface of the test explosive wedge which was fastened to a brass plate, shocking the opposite side of the plate by an explosive detonation, and observing with a smear camera the arrival of the shock wave at the free explosive surface. The arrival of the shock was detected by a change in the intensity of light reflected from the Mylar film surface. Simultaneously, shock and free surface velocities of the brass plate were determined. The initial particle velocity behind the shock front in the test explosive was determined by treating the explosive at the brass interface as an inert material and applying shock impedance relationships. Several points on the Hugoniot were determined for the unexploded explosives from the boundary conditions. Measurements of weak shock velocity near acoustic level were also determined to give tentative values for the initial slopes $(dp/dv)_0$ of the Hugoniot curves. Curves will be presented for the buildup shock velocity relative to initiation pressure.

MINUTES OF THE SPRING MEETING OF THE NEW ENGLAND SECTION AT THE U. S. COAST GUARD ACADEMY NEW LONDON, CONNECTICUT, ON MARCH 29, 1958

THE New England Section of the American Physical Society held its annual spring meeting on Saturday March 29, at the U. S. Coast Guard Academy, New London, Connecticut. Approximately sixty persons attended the meeting. At the morning session five contributed "Research Papers" were presented. At the afternoon session the following stimulating invited papers were heard:

Control of Frequency by Atomic Resonance, ARTHUR O. MCCOUBREY, *The National Company*.
Scattering of Electrons by Ultrasonic Waves in Superconductors. ROBERT W. MORSE, *Brown University*.
Some Aspects of the Controlled Fusion Program. JOHN M. GREENE, *Project Matterhorn*.

ROBERT F. KINGSBURY, *Secretary-Treasurer*,
New England Section

Research Papers

1. Sky Noise Measurements at the Sea Horizon. L. J. FREE, *U. S. Navy Underwater Sound Laboratory*.—The design of infrared receivers for naval vessels requires a knowledge of background noise at the sea horizon. The horizontal wave-number distribution of noise from the sky immediately above and the sea immediately below the horizon was measured during 1956 and 1957. The range of wave numbers measured was from 0.125 to 2 cycles per degree. The results are graphed in terms of the one-dimensional angular Wiener spectrum of the background as a function of the horizontal wave number. The analyzing equipment used for the measurements is also described.

2. Study of Molecules by Electron Bombardment.* MORTON A. FINEMAN AND AMERICO W. PETROCELLI, *Providence College*.—Negative and positive ions are formed by several different processes on bombarding molecules with slow electrons. If the appearance potential of an ion for a given process is known, it is possible to determine one or more of the following properties of molecules, radicals, ions, and atoms: bond dissociation energies, ionization potentials, electron affinities, and heats of formation. However, before the above quantities can be obtained it is necessary (1) to identify the ion formed as to its sign and mass, (2) to determine the appearance potential for the process, (3) to establish the actual process corresponding to the appearance potential, (4) to determine the kinetic energy of all the fragments upon their formation, and finally (5) to establish the electronic states of the various particles. A Lozier apparatus incorporating the retarding potential method for obtaining an essentially monoenergetic electron beam has been constructed. A study of nitrogen with the Lozier apparatus has confirmed the results of Fox and Hickam[1] on the formation of N_2^+ ion in three different electronic states. The formation of N^+ ions by three different processes depending on the excited state of the fragments has been seen at still higher electron energies. These results confirm some earlier work of Frost and McDowell.[2] It is possible with these data to establish the dissociation energy of N_2 as 9.76 ev.

* Supported in part by a U. S. Atomic Energy Commission Contract.
[1] R. E. Fox and W. M. Hickam, J. Chem. Phys. **22**, 259 (1954).
[2] D. C. Frost and C. A. McDowell, Proc. Roy. Soc. (London) **A236**, 278 (1956).

3. Acoustic Properties of Steam. R. B. LINDSAY AND DAYTON D. EDEN, *Brown University.*—An ultrasonic fixed path interferometer will be described, designed for investigating certain properties of steam at high pressures (up to 200 atmos) and temperatures (up to 500°C). The instrument is being used as a tool to study sound velocity and absorption as a function of temperature and pressure. It is anticipated that knowledge of the behavior of the sound velocity will aid in determining the equation of state of steam at these temperatures and pressures and that the experimental absorption values will directly indicate the presence and significant parameters of possible "relaxation" mechanisms involving the transfer between the excess acoustic translational energy of the molecules and the internal energy states of the molecules. This latter phenomenon manifests itself by an increase in the sound absorption over that due to effects external to the molecule; i.e., those associated with viscosity and heat conduction. The term "relaxation" is used here since the phenomenon of increased sound absorption comes about through the tendency of the excited internal molecular states to revert or relax to their equilibrium distribution, an average time τ after their excitation, releasing energy back to translational motion. This process leads to a phase difference between excess pressure and excess density and therefore an increased attenuation of the sound wave. The excess absorption coefficient per wavelength reaches a maximum when $\omega=\omega_0=1/\tau$ (ω is the angular frequency) and falls toward zero at larger or smaller ω, leaving only the classical value. The relaxation time τ is also a function of static pressure. However, for a given pressure it has a particular value for each type of internal mode of excitation of the molecules; (i.e., rotational and vibrational). Therefore, absorption data over wide pressure ranges can be of value in understanding the water molecule.

4. Some Experimental Aspects of Absolute Radiometry. A. J. DRUMMOND, *Eppley Laboratory, Inc.*—Recently the Radiation Commission of the International Association of Meteorology (IUGG) recommended the introduction, universally, of a standard pyrheliometric scale to which all measurements of solar and terrestrial radiation should be referred. The physical basis of the new scale is discussed and a summary presented of the author's own contribution to this object, made in the South African Weather Bureau. Whenever the establishment of the true scale of radiation intensity, using the sun as source, is attempted difficulty arises, with ground-based observations, from the variable nature of the circumsolar sky radiation and the uncertain state of knowledge, at present, of the angular distribution of this indirect flux. An important aspect of the planned research program, at the Eppley Laboratory, in radiometry is the realization of the fundamental radiation scale through the employment of very carefully controlled tungsten-filament lamps, up to 5 kva in power. An assessment is being attempted of the errors inherent in the two types of standard pyrheliometer (which essentially define the International Pyrheliometric Scale, 1956) and of the deviation of the IPS from a radiation datum independent of source and detector.

5. Fluctuations and Irreversible Processes. D. L. FALKOFF, *Brandeis University.*—In recent years, due mostly to the work of Onsager, a satisfactory theory of irreversible processes has been developed which is applicable to a wide range of phenomena beyond the scope of conventional thermodynamics. This work has its basis in the theory of fluctuations. Callen has also established a generalized Nyquist theorem relating the equilibrium fluctuation of thermodynamic variable to the dissipative element characterizing the irreversible process for the same system. The connection between these approaches will be discussed and their common statistical basis exhibited.

MINUTES OF THE MEETING OF THE SOUTHEASTERN SECTION HELD AT REDSTONE ARSENAL, HUNTSVILLE, ALABAMA, APRIL 10, 11, AND 12, 1958

THE twenty-fourth meeting of the Southeastern Section of the American Physical Society, held at Redstone Arsenal on April 10, 11, and 12, 1958, was attended by about 365 physicists from the region. The arrangements at Redstone Arsenal were made by Roger Clapp, Jr.; the program was planned by another committee chaired by I. G. Foster. The program of 21 invited and 67 contributed papers appears below. Titles of 4 invited lectures and 4 additional papers related to physics teaching are recorded in the *American Journal of Physics*. The dinner address was given by Norman J. Oliver, Air Force Cambridge Research Center. During the meeting the Section chose Loyola University, New Orleans, Louisiana, as the site of its 1959 meeting on April 9, 10, and 11. The Section also elected the following as its officers for 1958–1959: Vincent Parker, Louisiana State University, *chairman*; Paul Shearin, University of North Carolina, *vice-chairman*; Howard Carr, Alabama Polytechnic Institute, *secretary*; Myron McCay, University of Chattanooga, *treasurer*; and Joe Fowler, Oak Ridge National Laboratory, *executive committeeman*. Robert Lagemann, of Vanderbilt University, is the retiring chairman.

HOWARD CARR, *Secretary*
Southeastern Section
American Physical Society

Spectroscopy

(M. S. MCCAY presiding)

Invited Papers

A1. Interferometry and Isotopic Assay. JOHN H. WISE, *Washington and Lee University.*

A2. Application of the Echelle Spectrograph to Zeeman Spectroscopy. PAUL M. GRIFFIN, *Oak Ridge National Laboratory.*

A3. An Application of a Digital Computer to the Zeeman Problem. K. L. VANDER SLUIS, *Oak Ridge National Laboratory.*

Contributed Papers

A4. Infrared Intensities and Bond Moments in Phosgene and Thiophosgene.* R. J. LOVELL† AND E. A. JONES, *Vanderbilt University.*—Infrared intensities have been measured by the Wilson-Wells' pressure-broadening technique for the ν_1, ν_2, and ν_4 bands of $COCl_2$ and $CSCl_2$. The values of the bond moments and effective charges calculated for these molecules are

$COCl_2$

$\mu_{CO}=3.91\text{D}(C^+\rightarrow O^-)$ $\quad\mu'_{CO}=4.08$ D/A

$\mu_{CCl}=2.91\text{D}(C^+\rightarrow Cl^-)$ $\quad\mu'_{CCl}=-8.10$ D/A

$CSCl_2$

$\mu_{CS}=0.697\text{D}(C^+\rightarrow S^-)$ $\quad\mu'_{CS}=3.54$ D/A

$\mu_{CCl}=0.393\text{D}(C^+\rightarrow Cl^-)$ $\quad\mu'_{CCl}=-4.21$ D/A

These values were chosen from the possible solutions of the bond moment equations with the aid of an analysis of the other molecular parameters known for these two molecules. This analysis also serves to help test the applicability of the bond moment assumptions to these molecules.

* Based on a thesis submitted by R. J. Lovell in partial fulfillment of the requirements for the Ph.D. degree.
† Present address: Department of Physics and Astronomy, The University of Tennessee.

A5. Vacuum-Grating Spectrograph for the Infrared.* JOHN A. HERNDON† AND ALVIN H. NIELSEN, *The University of Tennessee.*—A vacuum-grating spectrograph has been designed and constructed using a modified Pfund type optical system. Incorporated in the instrument is a Fabry-Perot calibrating system which makes it possible to obtain measurements with an absolute accuracy of about ± 0.01 cm^{-1}. The instrument is housed in a large vacuum tank and is operated by means of synchro control systems. There are at present four gratings available for use in the spectrograph, which span the region from 400 to 8500 cm^{-1}. The spectrograph has been tested and has produced data with a resolution of 0.1 cm^{-1}. Slides showing the details of the instrument will be shown.

* Supported in part by the Office of Ordnance Research, U. S. Army.
† Now at Bell Telephone Laboratories, Murray Hill, New Jersey.

A6. Infrared Spectra and Molecular Constants of $N^{14}O_2$ and $N^{15}O_2$.* EDWARD T. ARAKAWA† AND ALVIN H. NIELSEN, *The University of Tennessee.*—The infrared spectra of $N^{14}O_2$ and $N^{15}O_2$ were observed under high dispersion with gas pressures up to 15 cm of $N^{14}O_2$ and 4 cm of $N^{15}O_2$ in a 20 meter absorption cell. Ten bands of $N^{14}O_2$, eight with well-resolved rotation lines; and nine bands of $N^{15}O_2$, seven with well-resolved rotation lines, were observed. The band centers of these bands were determined, from which all the ω_i and x_{ij} were calculated. By making use of the very good assumption that the potential constants are the same for isotopic molecules, the four force constants in the most general quadratic potential function were found to be $f_d=10.927\pm0.065$, $f_\alpha=1.125\pm0.003$, $f_{dd}=2.038\pm0.065$, and $f_{d\alpha}=0.390\pm0.020$ (all in millidynes/A). The following ground-state rotational constants were obtained from the rotational structures of the observed bands using symmetric top combination relations: for $N^{14}O_2$, $A=8.003$, $B=0.434$, $C=0.412$; and for $N^{15}O_2$, $A=7.642$, $B=0.434$, $C=0.410$ (all in cm^{-1}). Theoretical spectra, calculated for type A and type B bands by substituting these rotational constants into the asymmetric top equations gave excellent agreement when compared with the observed spectra. The partition function ratio for $N^{15}O_2$ to $N^{14}O_2$ is found to be 1.1080 at 25°C.

* Supported by the Office of Ordnance Research, U. S. Army.
† Now with Health Physics Division, Oak Ridge National Laboratory.

A7. Hindered Rotation and Translation of Chain Molecules.* W. E. DEEDS, *The University of Tennessee.*—The lowest frequency modes of chain molecules in a gas have zero frequency, corresponding to free rotation and translation. In liquids and solids, these modes are inhibited by intermolecular forces and become low frequency vibrations. These vibrations have been analyzed both classically and quantum-mechanically assuming for each degree of freedom a one-term potential function with arbitrary exponent. Even if the intermolecular forces are assumed to be linear, some of the vibrations are nonlinear, so that the resulting bands have temperature-dependent frequencies and strong overtones. The temperature dependence determines the proper exponent in the appropriate terms of the potential function, since the frequency varies as the $(n-2)/2n$ power of the absolute temperature, where n is the exponent in the potential function and is not necessarily integral. For typical hydrogen-bonded polymers with one bond per repeating unit, the theory predicts infrared and Raman bands at frequencies below about 100 cm^{-1}, some of which will have different temperature dependence than others, to aid in assignment. The greater the temperature dependence, the stronger the overtones, and the odd overtones should be particularly strong.

* Supported in part by The Chemstrand Corporation.

A8. 3303-A Emission from Sodium Ejected into the Upper Atmosphere.* C. DEWEY COOPER, *University of Georgia.*—During the early morning twilight on November 26, 1957, two kilograms of sodium were vaporized from a rocket over an altitude range of 75 to 150 km above Sacramento Peak, New Mexico. The sodium was ejected between 0557 and 0559 M.S.T. Visible and ultraviolet light from the yellow cloud were recorded with spectrographs. Both the 5893-A and 3303-A resonance lines were observed with the yellow line at least 100 times more intense than the ultraviolet line. Members of the sharp or diffuse series were not detected. If the 3303-A line is excited by a chemical process, then the yellow line should be only 2 or 3 times more intense than the ultraviolet line. Theoretical calculations[1] in which resonance scattering is assumed predict the ultraviolet line to be at least 70 times weaker than the yellow line. The observation of the 3303-A line with an intensity of less than one hundredth of the 5893-A line provides conclusive proof that the sodium twilight flash is due to the resonance scattering of sunlight.

* This research supported by Air Force Cambridge Research Center.
[1] C. D. Cooper, Bull. Am. Phys. Soc. Ser. II, 2, 284 (1957).

A9. Microwave Absorption of Mixtures of Dipolar Liquids in Solution in Nonpolar Solvents.* P. K. KADABA† (introduced by J. R. Lawson), *University of Kentucky.*—With a view to extend Schallamach's[1] investigations on the dielectric relaxation of mixtures to the microwave region and to simpler liquids and also with the hope of measuring the size of the regions involved in the relaxation process, ternary mixtures involving two unassociated polar liquids in a nonpolar solvent were investigated at a frequency of 16 200 Mc/sec. The dipolar components of the mixture chosen were nitro-compounds, nitrobenzene and nitriles. As the loss factor-temperature curves of these compounds in n-heptane did not show any clear tendency to move closer as regards the separation of the two peaks in the first set of measurements in the low concentration range, the measurements were extended to higher concentrations using cyclohexane and n-dodecane as solvents. It was surprising to note the distinctness of the two maxima even at higher concentrations in all the mixtures, particularly in the case of very similar nitrobenzene and o-nitrotoluene. The results seem to indicate that the mixtures chosen do not tend to one relaxation time but that each dipolar liquid retains its own. It would be interesting to compare the present curves with curves for two component mixtures with only one polar component present.

* This work was supported by the National Science Foundation.
† Now at Newark College of Engineering.
[1] A. Schallamach, Trans. Faraday Soc. 42A, 180 (1946).

Nuclear Physics

(T. M. HAHN, JR. presiding)

Contributed Papers

B1. Comparison of Level Densities for Nuclei of Different Even-Odd Character from Nitrogen-Induced Reactions. C. D. GOODMAN AND A. ZUCKER, *Oak Ridge National Laboratory.**—Information about the densities of energy levels in nuclei as a function of excitation energy can be obtained from measurements of the energy distributions of reaction products (e.g., protons, deuterons, and α particles) from nitrogen-induced reactions. When the level density functions for several different residual nuclei from a single target element are compared, an ambiguity exists in that differences in the functions can be ascribed either to the characteristics of the residual nuclei or to those of the observed particle. For example, it is not certain how to compare the yields of spin-zero α particles with spin-one protons. Comparison of data obtained from several different target elements bombarded in the Oak Ridge National Laboratory 63-in. cyclotron reduces the ambiguity and suggests that the level densities in even-even nuclei are an order of magnitude lower than in neighboring odd-A nuclei.

* Operated for U. S. Atomic Energy Commission by Union Carbide Corporation.

B2. Spontaneous Fission Neutron Yield of Natural Uranium. A. W. WALTNER AND B. B. LEONARD, *North Carolina State College.*—A measurement of the spontaneous fission neutron yield of natural uranium has been made by the activation of approximately 1500 l of $KMnO_4$ solution in a subcritical assembly containing over 5000 lb of natural uranium. The $KMnO_4$ solution was used as the moderator and reflector for the assembly. By filtering a large volume of this solution sufficient manganese activity is removed as MnO_2 by the Szilard-Chalmers effect to provide an accuracy of 1.5% in the measurement. However, since the total efficiency of the MnO_2 extraction process was not known to this high degree of accuracy, comparison of the activation by Pu-Be sources of known strength superimposed over the uranium was made. This provided the spontaneous fission neutron yield of natural uranium in terms of the Pu-Be source calibration.

B3. Measurement and Analysis of Reactivity Values of Reactor Control Elements.* RAYMOND L. MURRAY AND THOMAS L. JACKSON,† *North Carolina State College.*—The change in nuclear reactor multiplication factor resulting from insertion of cylindrical neutron absorbers in the Raleigh reactor has been measured by two methods. The first makes use of a comparison with a previously-calibrated control rod; the second involves neutron counting rates in the subcritical region. The test materials were water solutions of boron and cadmium compounds. Analysis of the theoretical reactivity values was performed by two neutron diffusion theory models. A one-group approach to a determination of the thermal neutron flux led to predictions of the rate of neutron loss into the absorbing column; a two-group procedure using appropriate extrapolation distances allowed the direct computation of reactivity. Good agreement between the experimental measurements and calculated results was obtained.

* This research was supported in part by the Office of Ordnance Research, U. S. Army.
† U. S. Air Force.

B4. Transmission of Neutrons through Iron. H. E. HUNGERFORD, *Atomic Power Development Associates, Inc.*—An energy-independent solution of the neutron transport equation has been used to investigate the transmission of neutrons of various energies through large thicknesses of iron. The purpose of the study was to determine the effect of cross-section variations on the neutron attenuation properties of iron for large thicknesses and to examine the phenomenon of energy streaming through iron in detail. The model used was a monoenergetic isotropic point neutron emitter surrounded by an infinite iron medium. Ten neutron energies were chosen for investigation including 25 kev, one of the regions of the famous neutron cross-section holes. The calculations were taken to 500 cm from the source. The results of the calculations indicate the following neutron relaxation lengths (cm) in iron: 8-Mev neutrons—5.9 at 100 cm from the source, 7.0 at 500 cm; 1-Mev neutrons—4.6 at 100 cm; 0.1-Mev neutrons—2.8 at 100 cm; 25 kev neutrons—15 at 100 cm, 21 at 500 cm; 1-kev neutrons—6.8 at 100 cm, 12 at 500 cm; 1-ev neutrons—3.2 at 100 cm; and thermal neutrons—1.8 at 100 cm. A comparison of these results with experimental data will be given.

B5. 496-Kev—122-Kev Cascade in the Decay of Ba^{131}. J. RICHARD HASKINS, *Ordnance Missile Laboratories.*—Scintillation techniques have been utilized to measure conversion coefficients and the angular correlation anisotropy. The K conversion coefficient of the 496 kev transition was measured as $(10.5\pm1.0)\times10^{-3}$. A liquid source in 0.1 N HCl solution was used in the angular correlation measurements. A value for the anisotropy of 0.01 ± 0.02 was obtained with this source. This value should be considered tentative since extra nuclear fields may have a perturbing influence. Possible spin assignments will be discussed considering, also, other recent investigations of this isotope.[1,2]

[1] Vartapetian, Compt. rend. **243**, 1512 (1956).
[2] August, Campbell, and Goodrich, Bull. Am. Phys. Soc. Ser. II, **2**, 231 (1957).

B6. Coulomb Excitation of States in Pt^{195}. F. K. MCGOWAN AND P. H. STELSON, *Oak Ridge National Laboratory.*—Gamma rays of 99, 130, 140, 210, and 240 kev have been observed from Coulomb excitation of Pt^{195} (platinum target containing 60% Pt^{195}) with 3.0- to 5.5-Mev protons and α particles. The energy dependence of the gamma-ray yields indicates direct excitation of states at 99, 130, 210, and 240 kev. The 140-kev gamma ray is a cascade transition between states at 240 and 99 kev. These results contradict the conclusions reached by Bernstein and Lewis from measured excitation functions of the internal conversion electrons that levels at 31 and 130 kev are directly excited by Coulomb excitation.[1] The angular distributions of the 240- and 210-kev gamma rays and the 140-kev gamma ray in coincidence with K x-rays from internal conversion of the 99-kev transition have been measured with respect to the incident ion beam on a thick target. These measured distributions are consistent with an assignment of $\frac{1}{2}(E2)^{\frac{1}{2}}$, $\frac{1}{2}(E2+M1)^{\frac{1}{2}}$ with $(E2/M1)^{\frac{1}{2}}=0.375\pm0.015$, and $\frac{1}{2}(E2+M1)^{\frac{1}{2}}$ with $(E2/M1)^{\frac{1}{2}}=(0.13\pm0.03)$ for the 240-, 210-, and 140-kev transitions, respectively. The $B(E2)$ and $B(M1)$ for decay of these states have been determined.

[1] E. M. Bernstein and H. W. Lewis, Phys. Rev. **100**, 1345 (1955).

B7. Efficiencies of Sodium Iodide Crystals.* A. L. STANFORD, JR., AND W. K. RIVERS, JR., *Georgia Institute of Technology* (introduced by C. H. Braden).—Efficiencies for

monoenergetic gamma rays emanating from an axial point source and incident on sodium iodide crystals of 1.5-in. diameter and of various heights, have been calculated by numerical methods. The crystals considered are right circular cylinders of heights 0.125, 0.25, 0.375, 0.50, 0.75, 1.5, 2.0, and 3.0 in. Seventeen photon energies in the range from 0.025 to 10.0 Mev were used. Efficiencies for crystals of diameters other than 1.5 in. may be obtained from these results. Relative photoelectric efficiencies were not calculated. By similar numerical methods, angular correlation attenuation coefficients are being computed using the equations of M. E. Rose[1] for values of absorption coefficient from 0.123 to 40.0 cm^{-1} and source distance from 5 to 50 cm. These coefficients constitute a correction for finite solid angle of detectors used in measurement of angular distributions.

* This work was supported in part by the National Science Foundation.
[1] M. E. Rose, Phys. Rev. 91, 610 (1953).

B8. Study of Beta-Gamma Angular Correlation in Ir^{192}.* VINCENT SHIEL,† L. D. WYLY, AND C. H. BRADEN, *Georgia Institute of Technology*.—The angular correlation between the 670-kev beta group and the 468-kev gamma ray in the decay of Ir^{192} was studied using standard scintillation counter techniques with pulse-height selection in both channels. Data were taken for the beta channel set to about 550 kev and to about 420 kev. 10 000 real coincidences were recorded at each of three angles in each case. Background due to gamma-gamma coincidences was negligible. Within the statistical precision of the data the correlation is isotropic. This is not inconsistent with a first forbidden beta transition[1] for which $\Delta J=1$, assuming the ground-state spin of Ir^{192} to be 5.[2] Some data have been taken on the composite angular correlation of the 540-kev beta group and the 604- and 613-kev gamma rays.

* This work supported in part by a grant from the National Science Foundation.
† Present address: Wright-Patterson Air Force Base, Dayton, Ohio.
[1] Baggerly, Marmier, Boehm, and Dumond, Phys. Rev. 100, 1364 (1955).
[2] Shiel, Wyly, and Braden, Phys. Rev. 105, 1521 (1957).

B9. Millimicrosecond Time Analyzer for Pulsed Beam Nucleon Time-of-Flight Measurements.*† J. D. FULLER, M. AWSCHALOM, AND R. C. MOBLEY, *Louisiana State University*.—Nuclear events, detected in conventional fashion, are processed to yield uniform pulses approximately 10 mμsec long. A CRT electron beam, intensity modulated from cutoff and circularly swept at the pulsed beam repetition rate, displays these pulses as short arcs of light along a circular trace. Optically magnified and projected on a ring of 120 photomultipliers, the trace becomes subdivided into channels of approximately 1 mμsec width. Each channel consists in sequence of a 931-*A* photomultiplier, a pulse-height discriminator, a normally open gate circuit which closes on receiving an output signal from the discriminator of the channel immediately preceding it in space along the trace, and a recorder. With the channels thus interconnected only one pulse is recorded for every nuclear event detected. The time resolution of the analyzer becomes, therefore, not primarily a function of electronic component speed, but rather of channel number.

* This work was supported in part by the U. S. Atomic Energy Commission.
† Based on a March, 1955, proposal by R. C. Mobley (unpublished).

B10. Application of Pulsed Beam Techniques to Nuclear Spectroscopy. J. H. NEILER, J. H. GIBBONS, AND W. M. GOOD, *Oak Ridge National Laboratory*.—The combination of pulsed accelerator beam and multichannel timing system has recently been applied to a variety of problems in nuclear physics. These applications fall into two general categories: energy measurement and background reduction. Energy measurement has so far been restricted to neutron work in the kev[1] range and in the spectrometry of proton and deuteron reactions. A useful amount of background reduction may be accomplished in those cases where (a) the random background rate is appreciable or (b) the beam associated background has a time correlation. Examples of these applications and recent progress in instrumental techniques will be discussed.

[1] J. H. Gibbons, "Cross Sections of Kev Neutrons" to be presented at Southeastern Section of American Physical Society in Huntsville, Alabama, April 10–12, 1958.

B11. High Intensity Time-of-Flight Neutron Spectrometer. JOHN A. HARVEY, R. C. BLOCK, AND G. G. SLAUGHTER, *Oak Ridge National Laboratory*.—A high intensity time-of-flight neutron spectrometer for measuring partial cross sections from thermal to 10-kev neutron energies is now in routine operation at the Low Intensity Testing Reactor. The spectrometer consists of a stainless steel rotor 18 in. in diameter designed to spin up to 10 000 rpm, a 45-m vacuum flight path, a bank of BF_3 proportional counters, and a 256-channel magnetic core time analyzer. At 6000 rpm, a neutron burst 2.6 μsec wide is obtained, resulting in a resolution of 0.06 μsec/m. This equipment is being used to make direct measurements of scattering cross sections up to 200 ev for various nuclides. Results for W and Ag will be presented. Although the spectrometer was designed for partial cross section measurements, total cross sections of several nuclides have also been measured to check its performance. Thorium resonance parameters determined from total cross section measurements of thick and thin samples will be given.

B12. Analysis of Charge Spectrum for the Radioactive Decay Xe^{133}-Cs^{133}. ARTHUR H. SNELL AND FRANCES PLEASONTON, *Oak Ridge National Laboratory*.—The decay of the 5.3-day activity Xe^{133}-Cs^{133} consists of beta emission leading to a level in Cs^{133} at 82 kev, from which gamma emission and internal conversion take place in a rather even balance. The charge spectrum associated with this activity consists of two parts, one arising from atoms that excape internal conversion and the other from atoms that suffer internal conversion. In this work the latter distribution (charges 4 to 23) is compared with the charge spectrum previously observed in the same apparatus for the activity Xe^{131m}-Xe^{131}, in which internal conversion alone is involved. A very shallow dip which is present in Xe^{131m}-Xe^{131} at charges 11 and 12 appears again in Xe^{133}-Cs^{133} in accentuated form at charges 12, 13, and 14. There is relatively more intensity in charges 13 through 19 in the case of Xe^{133}-Cs^{133} than there is in Xe^{131m}-Xe^{131}. The difference in the shapes of the spectra probably arises partly from the higher $K/(L+M)$ conversion ratio in Xe^{133}-Cs^{133}, and partly from a combination in some of the Xe^{133}-Cs^{133} decays of a loss of electrons by shake-off as a result of the change of nuclear charge with electron loss as a result of the internal conversion. The dip at charges 12, 13, and 14 suggests an underlying structure of the total charge spectrum, in which subspectra are associated wtih the individual electron shells in which the vacancy cascades originate.

Invited Paper

B13. Some Problems of Controlled Fusion Research. ALBERT SIMON. *Oak Ridge National Laboratory*.

Cyclotron Design and Studies

(VINCENT E. PARKER presiding)

Invited Papers

C1. Harwell Accelerator Studies. N. MARSHALL KING, *University of Florida* (on leave from United Kingdom Atomic Energy Establishment).

C2. Program of High-Intensity Experiments for the Southern Regional Accelerator. V. P. KENNEY, *University of Kentucky.*

C3. Review of Beam Deflection Theoretical Studies. MORTON M. GORDON, *Oak Ridge National Laboratory.*

C4. Summary of Progress on the Southern Regional Accelerator. ROBERT S. LIVINGSTON, *Oak Ridge National Laboratories.*

Contributed Papers

C5. Design Considerations of a Variable-Energy FFAG Cyclotron. DONALD L. LAFFERTY, *University of Florida.*—Recent advances in accelerator theory indicate that the energy limit for constant-frequency proton cyclotrons can be extended from the present 20-Mev limit to energies in excess of 900 Mev by constructing the pole faces in the form of spiral ridges. The possibility of intense beams and variable energy has led us to study the design parameters for a 10–100 Mev machine. The preliminary study, based on the linearized equations of motion, suggests a choice of 4 poles in this energy range. The ridges should be rectangular in cross section with a linear spiral. There should be no difficulty from resonances in this region. A maximum field modulation of about 15% would be required to provide sufficient vertical focusing. The problems of the design and the choice of design parameters will be discussed.

C6. An FFAG Electron Cyclotron. KENNETH K. COBB AND DONALD L. LAFFERTY, *University of Florida.*—As part of the over-all study of the FFAG-type cyclotron, a 4 pole, spiral-ridge electron cyclotron has been designed and is nearing completion. The pole faces are built up of a large number of ½-in. steel rods in a mosaic pattern to give a magnetic field of about 20 gauss with a sinusoidal azimuthal modulation. The construction of the pole faces permits variation of the number of poles and the spiral angle, and allows corrections to be made to the field. The electrons will be injected at a radius of 3 in. and will be extracted at 19 in. with an energy of about 75 kev. rf power is supplied to the dees by an RCA TV-1 television transmitter operating on a frequency of 50 Mc. The energy range of the electron machine was chosen to cover the operating range of the 100-Mev proton machine being designed. The construction of the components will be described and pictures of the machine shown.

C7. Magnetic Field Calculations for the Electron Cyclotron. THOMAS B. ELFE, KENNETH K. COBB, AND DONALD L. LAFFERTY, *University of Florida.*—One of the more difficult problems encountered in the construction of the electron machine is that of determining the shape of the iron pole faces to give a specified field in the median plane. The usual assumptions are made regarding the properties of the magnet iron. The problem is then one of locating the equipotential surfaces with respect to the median plane. Several approaches to the problem of calculating the geometry of the iron will be discussed and results of the computer program will be presented.

C8. Magnetic Field Measurements in the FFAG Electron Cyclotron. WILSON M. BARNES AND DONALD L. LAFFERTY, *University of Florida.*—Magnetic field measurements in the electron cyclotron are necessary to enable field corrections by magnet adjustment; to permit "pre-testing" of the operation of the cyclotron using computer techniques; and to permit correlation between the residual field imperfections and the behavior of the beam during actual operation. The required information is derived by digital-computer analysis from point-by-point measurements obtained with a flux-gate magnetometer. The large number of measurements necessary (about 11 000) requires the use of an automatic data-reduction system to convert the measurements to the digital punched-card form required by the IBM 650 computor. The system developed for performing and processing the field measurements will be described.

C9. Regenerative Beam Extraction in Ordinary Cyclotrons. ERIC RODGERS, *University of Alabama.**—A Peeler-Regenerator system of beam extraction from synchrocyclotrons was first suggested by Tuck and Teng.[1] The theory was elaborated in three articles by K. J. LeCouteur,[2] and the method has been used successfully to bring out the beam in several synchrocyclotrons. Some of the approximations of LeCouteur are not valid for low-energy cyclotrons, but the method is applicable and should give an improved beam both in quality and intensity. The results of calculations by the author will be discussed.

* This work was done at Los Alamos Scientific Laboratory.

[1] J. T. Tuck and L. C. Teng, Chicago Synchrocyclotron Progress Report III, July, 1949, to July, 1950.

[2] K. J. LeCouteur, Proc. Phys. Soc. (London) **B66**, 25 (1953); K. J. LeCouteur and Lipton, Phil. Mag. **46**, 1265 (1955).

C10. Experiments with a 4-Sector AVF Electron Cyclotron. J. A. MARTIN, R. S. BENDER, AND C. D. GOODMAN, *Oak Ridge National Laboratory.**—The Oak Ridge National Laboratory 4-sector electron cyclotron, called Analogue I, is a fixed-frequency machine which accelerates electrons to an energy of 190 kev ($\beta=0.7$); it was built to study orbit properties of particles accelerated in an azimuthally varying field. Strong axial focusing is produced by azimuthal variation of the field, and isochronism is maintained by an increase in the average field with radius. The radial and axial focusing frequencies, ν_r and ν_z, were measured by rf knockout techniques; they are in reasonable agreement with calculations. The qualitative behavior of the beam agrees with theoretical expectations in that beam disturbances are seen at $\nu_r-\nu_z=1$, $\nu_r=\frac{1}{2}$, and $\nu_r+\nu_z=2$; as expected, the beam is lost at $\nu_r=2$. The average orbit period is constant within 1 part in 5000, as shown by the measured minimum energy gain of 140 ev per turn required to accelerate electrons to full energy.

* Operated for the U. S. Atomic Energy Commission by Union Carbide Corporation.

Solid-State and X-Ray Physics

(PAUL E. SHEARIN presiding)

Contributed Papers

D1. Changes in Thermoelectric Power of Silver and Gold with Cold Work at Liquid Nitrogen Temperature. E. W. KAMMER, *U. S. Naval Research Laboratory.*—The thermoelectric power of high purity silver and gold wires was measured during a sequence of plastic elongation at the temperature of liquid nitrogen. After certain amounts of elongation the specimens were annealed at room temperature to reduce the number of vacancy and interstitial imperfections generated by the cold working. The thermoelectric power was then remeasured at liquid nitrogen temperature without any intervening plastic or elastic deformation. Finally the specimens were annealed above the recrystallization temperature to remove cold work induced dislocations and again the thermoelectric power was measured at liquid nitrogen temperature. The changes in thermoelectric power following each anneal are consistent with the interpretation that increasing the number of vacancy and interstitial lattice imperfections tends to make the absolute thermoelectric power more negative; increasing the number of dislocations makes the absolute thermoelectric power more positive. This could explain the fact that many elements, particularly those in the first column of the periodic table, have positive absolute thermoelectric powers at or near liquid helium temperature. At low temperatures the electron scattering may be dominated by the large number of dislocations which are permanently incorporated into a crystal during its growth from the melt and not removable to any appreciable extent by subsequent annealing.

D2. Pyroelectric Effect in Lead Zirconate-Titanate. C. V. STEPHENSON, *Alabama Polytechnic Institute.*—Berlincourt[1] has reported the peculiar behavior of the pyroelectric output of polarized polycrystalline lead zirconate-titanate. This report is concerned with the further study of this effect. The total pyroelectric output can be separated into three different effects. The first region occurring at low temperatures up to about 375°C is the normal release of the polarization charge from a ferroelectric. A second region of interest occurs in the approximate temperature range 160°C–440°C. A third region occurs at high temperatures from above 600°C down to about 250°C. The experimental data showing the pyroelectric behavior of this material and possible explanations of the differ- effects will be presented.

[1] From Sandia Corporation Report SC-3859 (TR) by Don Berlincourt, Clevite Research Center, Cleveland, Ohio.

D3. Paramagnetic Resonance in X-Irradiated Potassium Chlorate.* A. R. HUGHES, W. B. ARD, JR., AND T. E. HASTY, *University of Alabama.*—The paramagnetic resonance spectrum of x-irradiated potassium chlorate has been observed. Four groups of strongly orientation-dependent lines have been found which appear to be due to the interaction of an unpaired electron with the chlorine nucleus. These hyperfine lines have an over-all separation which changes from a minimum near zero to a maximum of approximately 250 gauss as the crystal is rotated. The g values of the interacting electron lies near 2.01 and has a small anistropy. A strong single line with a g value near 2 is also observed. This line is believed to be due to an electron trapped in an ion vacancy.

* This work supported by the Office of Ordnance Research and the Research Committee of the University of Alabama.

D4. *K*-Series Fluorescence Yield Measurements of Low *Z* Elements. RICHARD E. JOHNSTON, WILLIAM F. FREY, AND JOHN I. HOPKINS, *Vanderbilt University.*—Some studies have been made to determine the *K*-series fluorescence yields of V^{51} and Mn^{55} using *EC* capture isotopes and a proportional spectrometer. The source used in the measurement of V^{51} was a thin electroplated preparation of the radioisotope Cr^{51}. For Mn^{55} the source was Fe^{55}. Both radionuclides decay by *K* capture with a half-life of 27.8 days and 2.94 years, respectively. The values obtained for the *K*-series fluorescence yield of V^{51} and Mn^{55} are 0.305 ± 0.027 and 0.308 ± 0.037, respectively. The limitations of the method will be discussed and a comparison of the results with other values will be made.

D5. Measurement of Low-Energy X-Ray Attenuation Coefficients in Low *Z* Elements. RANDALL W. CARTER, WILLIAM EVERETT HUNT, AND JOHN I. HOPKINS, *Vanderbilt University.*—A series of studies has been carried out to determine attenuation coefficients of several low Z elements for x-rays in the energy range from 6–14 kev. A Bragg spectrometer with a calcite crystal and a proportional spectrometer were utilized in the measurements. Suitable foil thicknesses have been prepared by the electrolytic, vacuum vaporization and rolling methods. It has been possible to measure the attenuation coefficients of nickel, copper, zinc, cobalt, aluminum, and chromium in the energy range indicated. Wherever possible the *K*-jump ratio has been determined from the absorption data. Results obtained are in very good agreement with calculated values reported by the National Bureau of Standards and are believed to be accurate within 3%. The experimental arrangement and results will be presented.

D6. Effects of Inhomogeneous Compression on Pure Quadrupole Resonances.* J. L. RANDALL AND W. G. MOULTON, *University of Alabama.*—The change in amplitude of the chlorine quadrupole resonance in $NaClO_3$ powder which has been subjected to high pressures has been reported previously.[1] These experiments were carried out with a superregenerative spectrometer. These experiments have been repeated utilizing a regenerative spectrometer and conventional recording techniques so that changes in line shape may be studied. The quadrupole line in unpressed powder has a width of 1.40 ± 0.05 kc/sec between inflection points, and the root second moment is 0.87 ± 0.05 kc/sec. In powder which has been subjected to a compression of 4×10^4 psi, (the highest pressure at which we could obtain good signal-to-noise ratio) the line is 1.90 kc/sec in width and has a root second moment of 1.67 ± 0.05 kc/sec. The integrated area under the absorption line drops at 22×10^3 psi to 40% of the integrated area of unpressed powder. The ratio of second moment to line width remains nearly constant over the pressure range studied.

* This work supported by grants from the Research Corporation and the University Research Committee.

[1] W. G. Moulton and D. L. Hollis, Bull. Am. Phys. Soc. Ser. II, 2, 282 (1957).

D7. Mechanical Properties of Thin Metallic Films.* D. B. KRAFT, T. P. STRIDER, AND J. W. BEAMS, *University of Virginia.*—The mechanical properties of thin evaporated films of gold and silver have been studied as a function of their thickness by the "bulge" method. At thicknesses of about 2×10^{-5} cm, the films show an increase in tensile strength with decrease in thickness. These values are in rough agreement

with measurements by the centrifugal method[1] on electrodeposited films of the same metals. From the stress-strain curves of the films of various thicknesses, it is possible to estimate the surface tension of the films at room temperature. The values found were the order of 10^3 dynes/cm in air, the value for gold being greater than that for silver. The curves also gave Young's moduli. An explanation of the data will be advanced.

* Supported by Office of Ordnance Research, U. S. Army.

[1] Beams, Breazeale, and Bart, Phys. Rev. **100**, 1657 (1955).

Invited Papers

D8. Observation of the Structure and Growth of Thin Metal Oxide Layers on Single Crystals. W. W. HARRIS, *Union Carbide Nuclear Company.*

D9. Frequency-Dependent Conductivity of Superconductors and the Gap Model. ROLFE E. GLOVER, III, *University of North Carolina.*

D10. Some Resent Studies on Imperfections in Crystals. LAWRENCE SLIFKIN, *University of North Carolina.*

Theoretical Physics

(L. D. HUFF presiding)

Invited Paper

E1. Observations on Low and Medium Energy Nuclear Physics in the USSR. BERNARD L. COHEN, *Oak Ridge National Laboratory.*

Contributed Papers

E2. Interpretation of Experiments Utilizing a Stopping Potential. R. D. BIRKHOFF, *Oak Ridge National Laboratory.*—If the current-voltage curve is measured for an evaluated parallel plate chamber, both of whose plates emit electrons in equal numbers, the energy distribution of these electrons may be obtained from derivatives of the curve if the angular distribution of emission is known. For electrons of charge e emitted normal to the surfaces each of area A,

$$N(V)=\frac{1}{eA}\left(\frac{di}{dV}\right)_V.$$

If the angular distribution is isotropic

$$N(V)=-\frac{1}{eA}\left[2V\left(\frac{d^2i}{dV^2}\right)_V+\left(\frac{di}{dV}\right)_V\right].$$

For a cosine angular distribution

$$N(V)=-\frac{1}{eA}V\left(\frac{d^2i}{dV^2}\right)_V.$$

The latter case is applicable to photoelectric and secondary emission experiments.

E3. Delta Modulation. ERICH PIERUSCHKA, *Ordnance Missile Laboratories* (introduced by T. A. Barr, Jr.).—A pulse code modulation system, termed delta modulation, which transmits only incremental signals representative of the deviation of the modulating signal from the previously transmitted signal will be discussed. By utilization of a binary pulse code of a single bit with delta modulation, a very simple transmission system is obtained. Alternatively, a significant improvement of signal-to-noise ratio is obtainable when a multiple bit pulse code is utilized. The simplification of both coding and decoding devices in the first system is obtained by use of an integrating feedback loop in the transmitter in which the input signal is approximated by a step function which is transmitted to the receiver by a pulse code of one unit. In this system a 50% greater band width is required than in PCM. The second method retains the principle of delta-modulation by use of n previously transmitted pulses for pulse generation in the receiver. The transmission system has a higher complexity than the normal PCM system. However, a smaller band width than that of PCM is required for an acceptable signal-to-noise ratio. The value of the noise reduction depends on band width and shape of the information spectrum, and may be between $4n$ and $10n$ decibels.

E4. Response of a Nonlinear System. J. P. HALLOWES, JR., *Ordnance Missile Laboratories* (introduced by T. A. Barr, Jr.).—The nonlinear phenomena engendered by a primitive form of a control system, the relay servomechanism,[1] are of interest. The dynamics of such a system are described by a second-order ordinary differential equation with a viscuous like damping term and a nonlinear restoring force. The nonlinear restoring force is zero for absolute values of the dependent variable less than a threshold value and a positive or negative constant for positive or negative values of the dependent variable respectively exceeding this threshold. Solutions for the autonomous equation are well known; solutions for the case when a sinusoidal forcing function is applied to the system are presented. The resonance curves found exhibit a deformation of the resonant peak in conformity with behavior expected in a nonlinear system with a "soft" restoring force. The multivalued regions of the resonance curve are shown to be regions where instability occurs by appealing to energy considerations for the system. The results of an experimental investigation of the system simulated on an analog computer are shown.

[1] H. K. Weiss, J. Aeronaut. Sci. **13**, 364 (1946).

E5. Hydromagnetic Surface Waves. E. G. HARRIS,* *The University of Tennessee.*—The properties of waves which propagate along the interface between a perfectly conducting gas and a magnetic field are studied theoretically. It is found that when the Alfvén velocity in the interior of the gas exceeds the sound velocity, normal mode solutions (free oscillations of the surface) do not exist. By formulating the problem as an initial value problem the reason for this behavior is analyzed.

* This work was supported by the U. S. Atomic Energy Commission.

E6. Theoretical Topics on Induced Polarization of Earth Materials. JOHN H. HENKEL, *University of Georgia*.—The phenomenon of induced polarization of earth materials is treated as an induced electromotive force, leading to a polarization constant which is included in the resistivity of polarizable materials. The transmission of sinusoidal electromagnetic waves through a polarizable earth is treated. The polarization induced in a two-layered earth by surface current carrying electrodes is treated theoretically and calculations are presented.

E7. Universal Fermi Interactions.* EUGENE GREULING, *Duke University*.—Feynman and Gell-Mann's *V-A* interaction[1] may be contradicted if the He^6 recoil experiments underway confirm the Rustad and Ruby data.[2] By assuming that in the interaction between Fermi particles, neutral fields have right-handed helicities and charged fields have left-handed helicities, the following universal interaction is obtained:

$$H=(G/\sqrt{2})(T_{\mu\nu}T_{\mu\nu}^{*}+h.c.). \quad (1)$$

$T_{\mu\nu}$ is a sum of the baryon tensors,

$$\bar{\psi}_{p(L)}\gamma_{\mu}\gamma_{\nu}\psi_{b(R)} \quad (b=n,\ \Sigma^0,\text{ and }\Lambda^0),$$

and lepton tensors, $\bar{\psi}_{\nu(R)}\gamma_{\mu}\gamma_{\nu}\psi_{a(L)}$ ($a=e^-$ and μ) which increase charge; (L and R) label the left-right helicities. H yields results identical to the Feynman-Gell-Mann theory of μ decay, but for nuclear β decay it contains the T interaction in the linear combination $S-T+P$ that may be needed to account for He^6 data. Predictions of (1) combined with the Feynman-Gell-Mann interaction will be compared with experimental observations.

* This work was supported in part by the National Science Foundation.
[1] R. P. Feynman and M. Gell-Mann, Phys. Rev. **109**, 193 (1958).
[2] B. M. Rustad and S. L. Ruby, Phys. Rev. **97**, 991 (1955).

E8. Magnetic Moments of Hyperons. W. G. HOLLADAY, *Vanderbilt University*.—The magnetic moment operator for a heavy particle field transforms as $S+V$ where S is scalar and V is the third component of a vector in isotopic spin space. It is known that the V part of the nucleon anomalous moment, which is usually attributed to the pion field, is much larger than the S part. Now it is attractive to assume that all baryons interact with equal strength with the pion field. This leads to the possibility in general that the hyperons have anomalous moments (at least their V parts) of the order of magnitude of the nucleon anomalies. Two exceptions exist to this general rule, the Λ^0 and Σ^0, which for reasons of symmetry have a vanishing V part of the magnetic moment. Possible contributions to the S part and hence of the size of the Λ^0 and Σ^0 moments will be discussed.

Astronomy

(CARL K. SEYFERT presiding)

Invited Papers

I1. Millimeter-Wavelength Observations of the Sun and Moon. ROBERT N. WHITEHURST, *University of Alabama*.

I2. Radio-frequency Observations of the Planet Jupiter. ALEX G. SMITH, *University of Florida*.

Contributed Papers

I3. Radio Observations of the Moon at 7.5 Millimeter Wavelength.* W. C. TYLER, R. N. WHITEHURST, AND F. H. MITCHELL, *University of Alabama*.—A Dicke-type radiometer has been used in conjunction with a 60-in. paraboloidal reflector of 0.6° beam width to receive radiation from the moon. A variation in lunar temperature with phase angle is observed and represents approximately a 30°K decrease from 4 days after full moon to just before new moon. Further observations are in progress to obtain data for temperature as a function of lunar phase angle over the complete cycle. A preliminary value of about 175°K for maximum lunar temperature is found. The calibration procedure by which these temperatures were obtained has been described previously.[1]

* This work was supported by the Office of Ordnance Research, U. S. Army.
[1] Whitehurst, Copeland, and Mitchell, "Solar Radiation and Atmospheric Attenuation at 6 mm Wavelength," J. Appl. Phys. **28**, 295 (1957).

I4. Solar Radiation at 8.6 Millimeter Wavelength.* R. R. WEAVER, F. H. MITCHELL, AND R. N. WHITEHURST, *University of Alabama*.—A Dicke-type microwave radiometer with an 18-in. paraboloidal reflector and a beam width of 2.8° has been used to measure solar radiation at 8.6-mm wavelength. Observations (summer 1957) indicate an effective solar temperature of 6500°K. An indirect calibration procedure developed in this Laboratory, which corrects for atmospheric absorption and does not require a knowledge of the complete antenna pattern, was used. The quoted temperature is in good agreement with previous measurements in this Laboratory at 6.0 and 7.5 mm, which show effective temperatures of 4500°K and 5600°K, respectively.

* This work was supported by the Office of Ordnance Research, U. S. Army.

I5. Three-Dimensional Classification from Schmidt 10° Objective Prism Spectra. KENNETH M. YOSS, *Louisiana State University*.—The dispersion, 110 A/mm at H_γ, and resolution of the University of Michigan Curtis Schmidt telescope is sufficiently high to permit not only spectral but also luminosity classification. Spectral type can be determined to within one or two subclasses, even for plates of poor definition. Luminosity can be determined to within one luminosity class, primarily by means of the ionized strontium line at λ 4077. The third quantity, *CN* absorption strength, is estimated from the break in the continuum at the λ 4215 band head, for stars of spectral type G0 to K5. *CN* absorption depends not only on luminosity, but on the age of the star. A correlation thus exists between *CN* absorption in giant stars and space velocity. A systematic three-dimensional classification of 10° objective prism plates is therefore a rapid method for detection of high velocity giants with weak *CN* absorption, that is, stars which are believed to be relatively older than the majority of stars in the solar region.

I6. A Seeing Compensator Employing Television Techniques. J. H. DEWITT, JR., ROBERT HARDIE, AND C. K.

SEYFERT, *Vanderbilt University.*—Short time variations in atmospheric refraction cause the apparent position of an object to vary at random over a range of a few seconds of arc. The use of television techniques permits very short exposures to be made on bright planets and at the same time makes possible a system of continuous position correction which eliminates one destructive effect of seeing. The 24-in. reflector of the Arthur J. Dyer Observatory of Vanderbilt University is used in the cassegrain form with an enlarging lens and light splitter. One image is fed to the orthicon, while the other is beamed on to photocells the outputs of which are used to center the image on the orthicon target. Positional displacements are overcome completely and with speeds as short as 1/1000 sec. The apparatus is currently being employed to photograph the planet Jupiter. The project is sponsored jointly by Vanderbilt University and WSM Television.

I7. Photoelectric Photometry of Stars. ROBERT HARDIE, *Vanderbilt University.*—The problems of setting up a photometer whose natural system of magnitudes and color indices is as close as possible to a standard system are considered and practical methods are described. A number of methods for carefully determining the transformation constants are discussed, along with an easy and accurate technique for measuring the extinction. Factors which limit the precision are emphasized.

I8. Photoelectric Two-Dimensional Spectral Classification for B Stars. DAVID L. CRAWFORD, *Vanderbilt University.*—A method of two-dimensional classification of B stars through solely photoelectric methods is described. One classification index is sensitive to the strength of the Balmer discontinuity in the spectrum, while the other is a measure of the total absorption of the Hβ line. Simultaneous photoelectric photometry was used to determine this later index. The high relative accuracy of the classification is of use in problems of galactic structure and of stellar evolution. Some of these applications will be mentioned.

Gases and Other Topics

(JESSE W. BEAMS presiding)

Invited Paper

J1. Flow of Noble Gases at Low Pressures through Porous Media and Capillaries. LOREN M. LUND, *Union Carbide Nuclear Company.*

Contributed Papers

J2. Effects of Driven Oscillations on Combustion in Tubes. WALTER W. WHARTON AND T. A. BARR, JR., *Ordnance Missile Laboratories.*—This paper describes results of experiments directed toward solving the problem of unstable combustion occurring in rocket motors. A high-fidelity driver unit has been used to drive oscillations in a glass tube during propagation of flames in the tube. The driven oscillations apparently destroy the boundary layer at the walls which results in a perfectly flat combustion zone in open tubes. At certain frequencies two reaction zones are obtained while at other frequencies the combustion zone tilts at about 45° angle and spins in the tube. Another phenomenon is that the burning rate apparently is sharply reduced by the oscillations. An attempt is being made to relate mathematically the coupling of the combustion energy to the energy of oscillation.

J3. Experiments in Thermal Ionized Gases at Redstone Arsenal. CHARLES CASON AND T. A. BARR, JR., *Ordnance Missile Laboratories.*—Preliminary investigation of suitable methods for producing thermally ionized gases has been completed to date. Ionization is produced by drawing an electric arc between a carbon electrode and a carbon nozzle through which is forced a stream of argon, helium, air, etc. By employing a power as low as 10 kw the produced ionization (probably from 1% to 5%) in the gas causes it to demonstrate many properties of a physical plasma. The presence of Mach diamond structure in the ionized gas in an environmental pressure of 3 mm to 10 cm Hg indicates supersonic flow may be easily produced in this manner. Future work in plasma studies will include a newly designed plasma generator which will use power up to 75 kw.

J4. Tensile Behavior of Cellulose Acetate Butyrate as a Function of Rate and Temperature. RICHARD E. ELY, *Ordnance Missile Laboratories* (introduced by T. A. Barr, Jr.).—The viscoelastic behavior of cellulose acetate butyrate is demonstrated by tensile data. Yield stresses are reported for six decades of rate and a wide temperature interval. Ultimate strain trends and moduli are reported for a lesser range of rates but for sufficiently low temperatures so that results from both the glassy and leathery phase were obtained. A high-speed tensile machine (pneumatically operated) and a standard tester were used for these tensile tests. Special cooling apparatuses were required to obtain temperatures of −320°F. The yield strength of this thermoplastic at 74°F, for example, increased over 200% with increasing rate. The "elastic" modulus data demonstrate the viscoelastic nature, that is, the truly elastic response is both highly rate and temperature dependent. The butyrate data, past data, and the results of other investigators are used to draw general conclusions regarding the mechanical behavior of high polymers for an extremely wide temperature interval and for a rate factor greater than one million.

J5. A Long Sensitive Time Cloud Chamber. CLARENCE W. METTENBURG,* JAMES L. KASSNER, JR., AND DONALD A. RINKER, *Missouri School of Mines and Metallurgy.*†—A Wilson type cloud chamber has been built which is capable of obtaining sensitive times exceeding 3 sec. The chamber is a diaphragm water floor type chamber similar in design to the one introduced by C. T. R. Wilson in 1933. The natural sensitive time of the chamber was lengthened with the use of several solenoid valves. A large solenoid operated valve is used to reach the sensitive region quite rapidly and 4 solenoid valves with smaller orifices are used to continue the expansion. These smaller valves prolong the expansion and compensate for the loss of supersaturation due to the heating of the sensitive region by the walls of the chamber. The expansion curve (expansion ratio *versus* time) was obtained by simultaneously photographing the liquid level, timer and sensitive

region of the chamber. A knowledge of the shape of the expansion curve will enable one to reduce background due to re-evaporation nuclei.

* Naval Ordnance Test Station.
† Assisted by a grant from Research Corporation.

J6. A Study of Background in a Long Sensitive Time Wilson Cloud Chamber. DONALD A. RINKER, JAMES L. KASSNER, JR., AND CLARENCE W. METTENBURG,* *Missouri School of Mines and Metallurgy.*†—This laboratory is in the process of developing a long sensitive time cloud chamber which is capable of very low background levels. The present paper deals specifically with re-evaporation nuclei, photo-chemical processes, and the sweep field as potential causes of background. A method has been developed to reduce drastically the number of re-evaporation nuclei present after an expansion and data is being taken to determine the threshold wavelengths of light in several gas-vapor combinations responsible for photo-chemical processes resulting in condensation nuclei.

* Naval Ordnance Test Station.
† Assisted by a grant from Research Corporation.

J7. Variation with Age and Geographical Location of Some Trace Elements in the Human Body.* ISABEL H. TIPTON, *University of Tennessee.*—During the past six years the UT-ORNL has employed spectrographic methods to analyze for 37 elements tissues from autopsies of some 150 individuals from seven regions in the United States, 50 individuals from five regions in Africa, 100 individuals from ten regions in the Pacific Islands and Asia, and nine individuals from one region (Switzerland) in Europe. Very interesting similarities and differences in the trace element pattern of individuals from different parts of the world have come to light from these analyses. For elements which are known to have a role in the body economy, the geographical variation is not large, reflecting for the most part the state of nutrition of the population (lowest in African natives from the poorer regions). For certain elements which may replace or complete with necessary elements in their normal roles, the geographical variation is striking. The concentrations of certain elements show a marked age dependence.

* In cooperation with Health Physics Division, Oak Ridge National Laboratory.

J8. Calibration of a Scintillation Spectrometer at Low Energies. JOHN C. VILLEFORTH, HARRY H. HUBBELL, JR., AND ROBERT D. BIRKHOFF, *Oak Ridge National Laboratory.*—The pulse height and resolution of a NaI(Tl) scintillation spectrometer have been calibrated from 279 to 8 kev. Calibration data were obtained from the gamma and K x-ray lines of Hg^{203}, Ce^{141}, Os^{191}, and Tm^{170}, as well as from the fluorescent K x-rays produced by bombardment of nine elements (from U to Cu) with x-rays from a 250 KVCP machine. The spectrometer response to a monochromatic line is a Gaussian curve whose width is proportional to the square root of the line energy. Since the spectrometer fails to resolve the K series lines, a better estimate of the resolution constant can be obtained by filtering out the $K\beta$ lines with an absorber of slightly lower Z than the radiator. In the case of the K lines of uranium, filtering reduced the excess broadening from 33% to 6%. Calculated correction curves permit a determination of the resolution constant from the observed profiles of either filtered or unfiltered K series. A knowledge of the line profiles expected may be used to detect the presence of unresolved lines. Some of the filters and radiators were made by casting appropriate chemical compounds in plastic.

J9. Measurement of Airborne Radioactivity. C. J. BRIDGMAN AND NEWTON UNDERWOOD, *North Carolina State College.*—The measurement of airborne radioactivity at locations where there is no electrical power available is becoming increasingly important. Apparatus has been devised for collecting air samples which utilizes a centrifugal blower and an electrical precipitator both operated from a storage battery. Analysis of some samples will be presented. Comparison is made with the usual filter techniques.

Symposium on Artificial Satellites

(CHARLES LUNDQUIST presiding)

Invited Papers

K1. Earth Satellites, Past and Future. WERNHER VON BRAUN, *Army Ballistic Missile Agency.*

K2. Temperature Control Problems of Artificial Satellites. GERHARD B. HELLER. *Army Ballistic Missile Agency.*

K3. Spatial Attitude Control of a Spinning Rocket Cluster. WALTER HAEUSSERMANN, *Army Ballistic Missile Agency.*

K4. Tracking Artificial Satellites; a New Astronomical Problem. J. ALLEN HYNEK, *Smithsonian Astrophysical Laboratory.*

Low-Temperature Physics

(WALTER GORDY presiding)

Contributed Papers

N1. Low-Temperature Specific Heat Measurements on $U^{233}O_2Rb(NO_3)_3$. J. W. T. DABBS, L. D. ROBERTS, AND G. W. PARKER, *Oak Ridge National Laboratory.*—The specific heat of $U^{233}O_2Rb(NO_3)_3$ at low temperatures is of interest in connection with the nuclear alignment of U^{235} and U^{233} since this compound has been used for a number of α particle and fission anisotropy experiments.[1] A sample of very high isotopic purity has been measured in the range 1.2–4.2°K. The sample contained 0.1% Np^{237} as a paramagnetic impurity for inducing rapid nuclear spin relaxation. The measurements determined

the contribution to the specific heat both from lattice vibrations and from the Schottky anomaly associated with the coupling of the U^{235} nuclear quadrupole moment to the crystalline electric field. The size of this coupling is of interest in interpreting the nuclear alignment experiments. The measurements were made in a new apparatus which incorporates a mechanical heat switch to make and break the thermal contact to the liquid He bath. Heat was introduced electrically, and a carbon resistor, calibrated against the vapor pressure of liquid He, served as a thermometer.

[1] Bull. Am. Phys. Soc. Ser. II, 3, 6 (1958), and references cited there.

N2. Low-Temperature Characteristics of Germanium *p-n* Junction Counters. F. J. WALTER, L. D. ROBERTS, AND J. W. T. DABBS, *Oak Ridge National Laboratory.*—Germanium surface *p-n* barriers, similar to those first used by Gossick and Mayer[1] have been found suitable for use as both α particle and fission fragment counters at liquid N_2 and liquid He temperatures. With about 1 v applied across the barrier, pulses of 0.5 mv have been obtained for 4.8-Mev α particles and correspondingly larger voltages have been obtained for fission fragments up to ~100 Mev. Under optimum conditions the α particle resolution for a 1-cm² surface barrier has been found to be 4% full width at half maximum, with reasonable stability.

[1] B. Gossick and J. Mayer, Rev. Sci. Instr. 27, 407 (1956).

N3. Magnetoresistance of Zinc.* S. A. ALI, C. G. GRENIER, AND J. M. REYNOLDS, *Louisiana State University.*—Variation of electrical resistance at low temperatures of zinc has been studied in fields up to 11 kg with the aid of high sensitivity voltage detection (1 mμv) and large current density (40 amp/cm²). The departure from linearity of the magnetoresistance as function of H is observed to consist of two separate quadratic variations, one characteristic of low fields and another of high fields, the separation between the two being 4.5 kg. The oscillations in magnetoresistance are found to correspond roughly to de Haas van Alphen oscillation.[1] The system of double peaks as observed[2] in Hall oscillations is also present in magnetoresistance oscillations, though with decreased amplitude. Field and angular dependence is in agreement with Alers[3] and Borovik.[4] Interesting features appear on comparison of period and amplitude of de Haas van Alphen, Hall effect, and magnetoresistance oscillations.

* Supported by the Office of Ordnance Research.
[1] J. S. Dhillon and D. Shoenberg, Trans. Roy. Soc. (London) A937, 248 (1955).
[2] Grenier, Reynolds, and Ali, Proceedings of the Fifth International Conference on Low-Temperature Physics and Chemistry (1957).
[3] Perry B. Alers, Phys. Rev. 101, 41 (1956).
[4] E. S. Borovik, Zhur. Eksptl. i Teoret. Fiz. 30, 262 (1956).

N4. Effect of Velocity on the Apparent Mass of an Object Moving through liquid Helium II.* B. J. GOOD, W. J. SCHULTIS, AND J. M. REYNOLDS, *Louisiana State University.*—The two-fluid model of liquid helium II assumes that the superfluid component of the liquid is nonviscous, incompressible, and irrotational. It was shown by Stokes[1] that the effect of such a fluid on the motion of an object through the fluid is to give to the object an apparent additional mass. Recent studies[2] of the motion of a torsional oscillator in liquid helium has verified this concept. At temperatures below 1.5°K where the helium is predominately superfluid, the experimental values of the apparent mass agreed very well with values calculated for a perfect fluid. There was, however, a significant deviation of the experimental from the calculated values of apparent mass near the λ point when the oscillator period was approximately 26 sec. In the experiment reported here, the effect of the period of oscillation on the apparent mass was studied for different periods in the range of 40 to 3 sec. It was found that the deviation decreased with a decrease in the period. The experimental value approached a value predicted by classical hydrodynamics when the entire body of helium was considered as a perfect fluid.

* Supported by the Office of Ordnance Research, U. S. Army.
[1] C. G. Stokes, Trans. Cambridge Phil. Soc. 8, 105 (1843).
[2] Reynolds, Good, and Schultis, Proceedings of the Fifth International Conference on Low-Temperature Physics and Chemistry, (1957).

N5. A Low-Temperature X-Ray Diffraction Camera.* THOMAS E. HUTCHINSON AND J. E. MILLER, *Clemson College.*—A Debye-Scherrer camera was adapted for studies of phase transformations in solids in a range from room temperature to that of liquid nitrogen. The apparatus in similar to that of to that of L. K. Jetter *et al.* Oak Ridge[1]; however, several marked differences arise due to the fact that the above cited low-temperature specimen chamber was used with a geiger-counter diffractometer. A brass drive rod, vacuum sealed by means of an O-ring, enables rotation of the specimen within the vacuum chamber. This rotation gives rise to smoother diffraction lines thus permitting more accurate densitometer readings. The coolant was pumped through a copper tubing wrapped closely around the specimen block. An inlet and outlet were provided which enabled the coolant to flow continuously. An automatic switching device permitted the required positive pressure to be applied to either of two Dewar bottles thereby guaranteeing continuous flow of the coolant through the tubing until the coolant was exhausted. This enabled long exposures to be made without the constant attention of the operator.

* Senior Thesis, Clemson College.
[1] Rev. Sci. Instr. 28, 1087 (1957).

Invited Paper

N6. Recent Experiments on the Heat Conduction of Metals at Low Temperatures. H. M. ROSENBERG, *University of Florida* (on leave from Clarendon Laboratory, Oxford University).

Nuclear Physics

(M. E. ROSE presiding)

Invited Paper

O1. Neutron Total Cross Sections in the kev Range. JOHN H. GIBBONS, *Oak Ridge National Laboratory.*

Contributed Papers

O2. Fission Cross Section for 23-Mev Protons on U^{238}. C. B. FULMER, *Oak Ridge National Laboratory.**—It has been shown[1] that fission cross sections in the medium energy region are essentially measures of total reaction cross sections. The absolute fission cross section for 23-Mev protons on U^{238} was measured by detecting directly the outgoing fission fragments

from high purity targets which were bombarded with the energy-analyzed external proton beam of the Oak Ridge National Laboratory 86-in. cyclotron. Preliminary data at 90° yield a value of 1.15±0.03 barns. When this is combined with known values of anisotropy of fission fragments from proton-induced fission and with cross sections for (p,xn) reactions for U^{238} a total reaction cross section of 1.25±0.04 barns is obtained. This is in approximate agreement with an extrapolation from the results of the optical model calculations of Glassgold and Kellog[2] for 17-Mev protons on gold.

* Operated for the U. S. Atomic Energy Commission by Union Carbide Corporation.
[1] G. H. McCormick and B. L. Cohen, Phys. Rev. **96**, 722 (1954).
[2] A. E. Glassgold and P. J. Kellog, Phys. Rev. **107**, 1372 (1957).

O3. Pion Production Multiplicity in π^--p Interactions.* V. P. KENNEY AND J. G. DARDIS, *University of Kentucky*.—Pion production in π^--p interactions has been studied near the 1-Bev resonance in data from the 10-in. University of California Radiation Laboratory liquid hydrogen bubble chamber. Preliminary measurements of 4-prong events show the ratio of π^0 decay electron pairs to double-production meson pairs to be (11±4)/(68±4) at 0.93 Bev/c, (9±2)/(94±4) at 1.10 Bev/c, and (14±3)/(120±7) at 1.24 Bev/c. Assuming that for each degree of multiplicity charge states are formed in proportion to their isotopic spin weights, the ratios of double pion production to single pion production inferred are (in the same order) 0.12±0.05, 0.36±0.12, and 0.28±0.09.

* Supported in part by the Faculty Research Fund of the University.

O4. Differential Elastic Neutron Scattering from Beryllium. J. L. FOWLER AND H. O. COHN, *Oak Ridge National Laboratory*.—The neutron differential elastic scattering cross section of beryllium has been measured at a number of energies between 0.7 Mev and 3.0 Mev. $T(p,n)$ neutrons were scattered by cylinders of beryllium and detected as a function of neutron scattering angle with a shielded propane recoil counter. The center-of-mass differential cross sections in the nonresonant region between 1.0 and 2.0 Mev shows an appreciable $\cos\theta$ term in the angular dependence, thus indicating a relatively large p-wave contribution. The elastic scattering in the region of the broad peak in the total cross section around 2.8 Mev changes from being nearly symmetric about 90° at 2.44 Mev to being strongly peaked forward at 2.92 Mev. Qualitatively, this suggests two resonances in this region—a resonance involving no parity change in forming the compound state, followed by a resonance in which the parity is changed. This information together with the data on the $Be^9(n,\alpha)$ cross section,[1] probably identifies the very broad state at about 2.9 Mev neutron energy as being formed by p-wave neutrons with $J=2+$ for the compound state of Be^{10}.

[1] P. H. Stelson and E. C. Campbell, Phys. Rev. **106**, 1252 (1957).

O5. π^--P Interactions at 1.85. Bev/c.* R. C. WHITTEN, *Duke University* (introduced by E. Greuling).—This paper reports some experimental results concerning the elastic and inelastic scattering of protons by pions having a momentum in the laboratory system of 1.85 Bev/c. The elastic scattering data are consistent with diffraction by a sphere of radius 0.85 f and opacity 0.89. The forward scattering amplitude was found to be in agreement with that derived from the dispersion relations. Investigation of the inelastic scattering with respect to the multiplicity of pion production and charge-state ratios disclosed that there is agreement with the predictions of the Fermi statistical model for an interaction radius of 2.0 f. The charge-state ratios also showed some agreement with the excited isobar model. The angular and Q value distributions of the particles emerging from inelastic interactions showed little agreement with either model.

* Based on a thesis submitted by R. C. Whitten in partial fulfillment of the requirements for the M.A. degree.

O6. Cross Sections for (p,n) Reactions in Isotopes of Pd, Cd, and Te. C. H. JOHNSON, A. GALONSKY, AND C. N. INSKEEP, *Oak Ridge National Laboratory*.—Analyzed protons from the 5.5-Mev van de Graaff accelerator were used to bombard isotopically enriched targets, and neutrons were detected by a flat response 4π detector.[1] In this manner the (p,n) cross sections were determined to an accuracy of ±10% for proton energies from 3.0 to 5.5 Mev for 4 palladium, 5 cadmium, and 4 tellurium isotopes. For each isotope, except those with thresholds near or above 3 Mev, the cross section increases strongly and smoothly with proton energy: from about 0.3 mb at 3 Mev to 55 mb at 5.5 Mev for the Pd isotopes, about 0.12 mb at 3 Mev to 50 mb at 5.5 Mev for the Cd isotopes, and about 0.05 mb at 3 Mev to 28 mb at 5.5 Mev for the Te isotopes. At any given energy in this energy region the isotopes of one element have cross sections differing from each other by only about 20%. There is a definite tendency for the heavier isotopes of a given element to have the higher cross section. These striking regularities indicate that the predominate isotope effect on these cross sections is simply the reduction of Coulomb barrier with increasing mass number and, therefore, with increasing radius.

[1] R. L. Macklin, Nuclear Instr. **1**, 385 (1957).

O7. Spherical Electrostatic Spin Rotator for Electron Polarization Measurements. A. GALONSKY, H. B. WILLARD, A. R. BROSI, B. H. KETELLE, H. O. COHN, AND N. H. LAZAR, *Oak Ridge National Laboratory*.—In order to observe an asymmetry in Mott scattering of β particles from gold it is necessary to convert the longitudinal spin of the electron into a transverse spin. This has been done by bending the electrons through 136° with the electric field in a 1-cm gap between two spherical aluminum plates of mean radius 25 cm. The 624-kev Cs^{137} K electrons are transmitted when the plates are charged to ±17.5 kv. With a ±6° azimuthal acceptance angle at the source the transmission is 5×10^{-4}. Because of relativistic effects there is no radial focusing, but in the direction of the expected scattering asymmetry the image of a 1.5-mm source is <2.5 mm wide at half maximum. Electrons which are scattered from the plates (and possibly depolarized) are not focused and appear as tails on the intensity distribution of the image. By inserting lucite apertures between the plates the ratio of peak to tail intensity for a P^{32} source has been made >100. Polarization measurements of P^{32} electrons are in progress.

O8. Positron Lifetimes in Different Concentrations of Free Radical in Pure Dry Benzene. R. L. DOUGH, *North Carolina State College* (introduced by A. C. Menius, Jr.).—The lifetime of positrons in a solution of a free radical, in this case diphenyl—picryl—hydrazyl, and pure dry benzene have been studied. A mμsec coincidence system of the Bell, Graham, and Petch type was used. The results show that the addition of the free radical quenches the long lifetime component. This is shown as a function of concentration. The results are in agreement with other data.[1]

[1] S. Berko and A. Zuchelli, Phys. Rev. **102**, 724 (1956).

O9. Meson Production in P-P Collisions at 2.7 Bev.* W. M. BUGG AND D. T. KING, *University of Tennessee*.—A stack of twelve Ilford G-5 600 μ nuclear emulsion plates were exposed to the 2.7-Bev proton beam of the Brookhaven Cosmotron. The track-following technique was used to find those nuclear events which simulated collisions with pure hydrogen nuclei. Preliminary observations have been completed on a set of 47 two-prong stars. The angular and momentum distributions

of the nineteen identified charged pions have been calculated. The angular distribution is consistent with isotropic emission in the center-of-mass system and the average momentum is approximately 200 Mev/c. Both the angular and momentum distributions are consistent with the results of previous workers.[1]

* Supported by National Science Foundation, Grant G2405.
[1] Cester, Hoang, and Kernon, Phys. Rev. 103, 1443 (1956).

O10. Iron Free Double Focusing Beta-Ray Spectrometers.* Q. BAIRD, J. C. NALL, AND S. K. HAYNES,† *Vanderbilt University.*—In order to achieve high resolution and good reliability at low electron energies, a Svartholm-Siegbahn double focusing spectrometer without iron has been built at Vanderbilt University. The coil arrangement for producing the necessary $H/r^{\frac{1}{2}}$ field is similar to that of Moussa and Bellicard, but the spectrometer proper has been completely re-engineered and has a 30-cm mean radius. Three pairs of Helmholtz type coils are used for compensating the earth's field. The current supply for the spectrometer is a dc generator with a negative feedback system for reduction of noise. The current is controlled by a double rotating coil system. One coil is in the spectrometer field and the other is in a permanent magnet field. An amplified ac error signal is detected for control of the generator output. The instrument uses a continuous flow Geiger counter with very thin organic film windows for particle detection. The resolution can be varied from about 0.15% to about 0.5% depending on the transmission desired.

* Design and construction supported by a grant from the National Science Foundation.
† Now at Michigan State University.

O11. Study of the K and L Auger Spectra of $Au^{190}-Hg^{190}$.† J. C. NALL, Q. BAIRD, AND S. K. HAYNES,* *Vanderbilt University.*—An iron free, double focusing beta-ray spectrometer (described in a previous paper) was used to obtain the electron spectrum of Au^{190}–Hg^{190}. A momentum resolution of 0.35% was used for this work. In the K Auger region the relative intensities of the main groups (KLL, KLX, KXY) were determined as well as the relative intensities of many lines within the main groups. The global K Auger yield, and thus the fluorescence yield, was calculated, as well as various subgroup yields. In the L Auger region (approximately 5 to 15 kev) the relative intensities of the main groups (LMM, LMX, LXY) are given as well as the relative intensities of many lines within the main groups. Information similar to the K Auger yield discussed above is given for the L groups. The effects of the Coster-Kronig process is discussed. L subshell conversion coefficients were also determined. Source and window making problems are mentioned.

† This work supported by a grant from the National Science Foundation.
* Now at Michigan State University.

Author Index to Papers Presented at the Huntsville Meeting

Ali, S. A.—N3
Arakawa, E. T.—A6
Ard, W. B., Jr.—D3
Awschalom, M.—B9
Baird, Q.—O10, O11
Barnes, W. M.—C8
Barr, T. A., Jr.—J2, J3
Beams, J. W.—D7
Bender, R. S.—C10
Birkhoff, R. D.—E2, J8
Block, R. C.—B11
Braden, C. H.—B8
Bridgman, C. J.—J9
Brosi, A. R.—O7
Bugg, W. M.—O9
Carter, R. W.—D5
Cason, C.—J3
Cobb, K. K.—C6, C7
Cohen, B. S.—E1
Cohn, H. O.—O4, O7
Cooper, C. D.—A8
Crawford, D. L.—I8
Dabbs, J. W. T.—N1, N2
Dardis, J. G.—O3
Deeds, W. E.—A7, G1
DeWitt, J. H., Jr.—I6
Dough, R. L.—O8
Elfe, T. B.—C7
Ely, R. E.—J4
Fowler, J. L.—O4
Frey, W. F.—D4
Fuller, J. D.—B9
Fulmer, C. B.—O2
Galonsky, A.—O6, O7
Gibbons, J. H.—B10, O1
Glover, R. E., III—D9
Good, B. J.—N4
Good, W. M.—B10
Goodman, C. D.—B1, C10
Gordon, M. M.—C3
Grenier, C. G.—N3
Greuling, E.—E7
Griffin, P. M.—A2
Haeussermann, W.—K3
Hallowes, J. P., Jr.—E4
Hardie, R.—I6, I7
Harris, E. G.—E5
Harris, W. W.—D8
Harvey, J. A.—B11
Haskins, J. R.—B5
Hasty, T. E.—D3
Haynes, S. K.—O10, O11
Heller, G. B.—K2
Henkel, J. H.—E6
Herndon, J. A.—A5
Holladay, W. G.—E8
Hopkins, J. L.—D4, D5
Hubbell, H. H., Jr.—J8
Hughes, A. R.—D3
Hungerford, H. E.—B4
Hunt, W. E.—D5
Hutchinson, T. E.—N5
Hynek, J. A.—K4
Inskeep, C. N.—O6
Jackson, T. L.—B3
Johnson, C. H.—O6
Johnston, R. E.—D4
Jones, E. A.—A4
Kadaba, P. K.—A9
Kammer, E. W.—D1
Kassner, J. L., Jr.—J5, J6
Kenney, V. P.—C2, O3
Ketelle, B. H.—O7
King, D. T.—O9
King, N. M.—C1
Kraft, D. B.—D7
Lafferty, D. L.—C5, C6, C7, C8
Lazar, N. H.—O7
Leonard, B. B.—B2
Livingston, R. S.—C4
Lovell, R. J.—A4
Lund, L. M.—J1
Martin, J. A.—C10
McGowan, F. K.—B6
Mettenberg, C. W.—J5, J6
Miller, J. E.—N5
Mitchell, F. H.—I3, I4
Mobley, R. C.—B9
Moulton, W. G.—D6
Murray, R. L.—B3
Nall, J. C.—O10, O11
Neiler, J. H.—B10
Nielsen, A. H.—A5, A6
Parker, G. W.—N1
Pieruschka, E.—E3
Pleasanton, F.—B12
Randall, J. L.—D6
Reynolds, J. M.—N3, N4
Rinker, D. A.—J5, J6
Rivers, W. K., Jr.—B7
Roberts, L. D.—N1, N2
Rodgers, E.—C9
Rosenberg, H. M.—N6
Schultis, W. J.—N4
Seyfert, C. K.—I6
Shiel, V.—B8
Simon, A.—B13
Slaughter, G. G.—B11
Slifkin, L.—D10
Smith, A. G.—I2
Snell, A. H.—B12
Stanford, A. L., Jr.—B7
Stelson, P. H.—B6
Stephenson, C. V.—D2
Strider, T. P.—D7
Tipton, I. H.—J7
Tyler, W. C.—I3
Underwood, N.—J9
Vander Sluis, K. L.—A3
Villforth, J. C.—J8
Von Braun, W.—K1
Walter, F. J.—N2
Waltner, A. W.—B2
Weaver, R. R.—I4
Wharton, W. W.—J2
Whitehurst, R. N.—I1, I3, I4
Whitten, R. C.—O5
Willard, H. B.—O7
Wise, J. H.—A1
Wyly, L. D.—B8
Yoss, K. M.—I5
Zucker, A.—B1

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